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B. T. GALLOWAY, *Chief of Bureau.*

THE PECAN.

BY

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Special Agent in Nut-Culture Investigations, Office of
Field Investigations in Pomology.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., March 20, 1912.

SIR: I have the honor to transmit herewith a paper entitled "The ecan," by Mr. C. A. Reed, Special Agent in Nut-Culture Investitions, prepared under the direction of Mr. A. V. Stubenrauch, xpert in Charge of Field Investigations in Pomology.

I recommend that this paper be published as Bulletin No. 251 of e Bureau series.

Respectfully,
B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE PECAN.

INTRODUCTION.

The pecan is one of the most important of the nut-bearing trees now grown in the United States, and within the area thought to be adapted to its culture no other agricultural or horticultural product which has appeared during recent years is attracting greater attention or being so widely exploited. It was not found by the early botanists nearer the Atlantic coast than western Alabama in the South and central Tennessee and Kentucky in the North, but with the progress of agriculture in the South the species has been carried eastward and widely distributed with apparent success over the eastern Gulf and South Atlantic States. It has also been sparingly introduced into many of the Northern States, including Ohio, Michigan, New York, Pennsylvania, Maryland, Delaware, New Jersey, and to a slight extent into the lower New England States. In the West it has received but little attention. A few planted trees may be found here and there from Washington to southern California, but pecan growing has not become an important industry west of the Rocky Mountains.

The evident age of not uncommon large trees near the Gulf coast indicates that the planting of pecans in the Southern States east and south of the area of the natural range of the species has been in progress for more than a century. The planting of orchards in those States began with seedling trees about 20 years after the Civil War. During the early nineties grafted and budded trees of named varieties appeared in sufficient numbers so that a few orchards of such trees were then planted, but comparatively few orchards of either seedling or grafted trees were planted previous to 1900. Since that time, especially during the past five years, the planting of pecan orchards in the Southern States has been taking place at a rapidly accelerating rate. In southern Mississippi, southern Alabama, central and southern Georgia, and northern Florida, large tracts of land, frequently several hundred acres in extent, are being planted to pecan trees and later sold to outside investors. For several years the demand for nursery-grown trees has been far beyond the supply, leading nurserymen booking orders for their entire output from six to eight months before the planting season. Most unusual interest is being manifested in pecan culture, and investments, which are large for an industry that is still in its infancy, are being made in spite of the fact that very few pecan orchards are as yet of sufficient age to have been in bearing long enough to furnish reliable data upon which to make safe estimates as to the probable yields of a given variety at any stated age in particular localities. Observations, accurate in themselves, on the bearing records of single trees here and there are frequently taken as the basis for estimates as to the probable yield of an entire orchard of the same variety or varieties, but as it usually develops that the trees making these records have grown under conditions of exceptionally favorable environment, the fallacy of such calculations is at once apparent. To be at all trustworthy, estimates as to future yields must be based on the average records of a great number of trees under normal conditions rather than of single trees which are conspicuous because of their abnormal production.

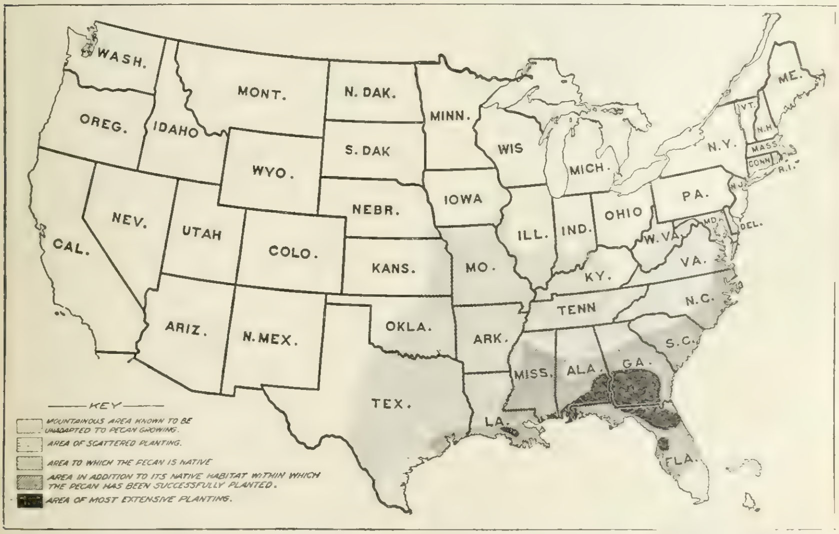
An erroneous impression to the effect that the pecan has no serious enemies in the way of insect pests or fungous diseases and that it is not affected by drought, freezing temperatures, or high winds has become prevalent among a considerable portion of prospective commercial and amateur planters. No agricultural product is without its natural enemies and other obstacles that must be overcome. When any plant is brought under cultivation and large contiguous areas are planted, the opportunities for the development and spread of the insects and diseases attacking it are greatly increased. The pecan is no exception to this rule, and in due time many serious enemies to it must be expected to appear. Among the insects that have already appeared are those which attack the fruit buds in early spring; girdlers which cut off the twigs during the latter part of the growing season, frequently causing branches with clusters of nuts to fall to the ground; webworms which defoliate the trees; shuckworms which destroy the nut by burrowing out the soft hull while immature; weevils which work in the nut itself; and borers which penetrate the body and main branches of the tree; besides a number of others less well known. A large number of fungous diseases also attack the pecan. The most important of these diseases is the pecan scab, which attacks the foliage, stems, and hulls of the young nuts of mature trees and which is sometimes very serious on late, rapidly growing trees of certain varieties in the nursery.

Investigations of the control of insects and fungous diseases attacking the pecan are receiving the attention of other investigators; a detailed discussion of these problems is therefore beyond the scope of this bulletin, which is designed to give such general information concerning the various phases of the pecan and its culture as is available at the present time.[1]

Long-continued rains at the blossoming time which interfere with pollination, late spring frosts which kill the buds or destroy the young nutlets, sudden drops of temperature in winter during which immature late growth may be severely frozen back, subtropical storms of such intensity as to blow the nuts off and sometimes to uproot grown trees, and droughts during the late summer months just as the nuts are maturing are inevitable obstacles which must be taken into consideration.

BOTANICAL CLASSIFICATION OF THE PECAN.

The pecan is an American species of nut-bearing tree belonging to the botanical family Juglandaceæ, which includes also the hickories, the walnuts, and the butternut. It has been variously known as *Juglans pecan*, *Carya olivaeformis*, and by other less common terms. The botanical name now commonly accepted is *Hicoria pecan.*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KEY
MOUNTAINOUS AREA KNOWN TO BE UNADAPTED TO PECAN GROWING.
AREA OF SCATTERED PLANTING.
AREA TO WHICH THE PECAN IS NATIVE
AREA IN ADDITION TO ITS NATIVE HABITAT WITHIN WHICH THE PECAN HAS BEEN SUCCESSFULLY PLANTED.
AREA OF MOST EXTENSIVE PLANTINGS.

FIG. 1.—Outline map of the United States, showing the range of the pecan exclusive of occasional plantings in the Western States and scattered trees throughout the West and North.

NATURAL DISTRIBUTION.

The pecan is wholly an American species found only in certain parts of the United States and Mexico. Figure 1 is an outline map of the United States showing areas within which the pecan occurs at the present time. From this map it will be seen that with the exception of a small area[1] in central Alabama, west of Montgomery, the eastern boundary of the pecan habitat is marked by an irregular line drawn southward across central Kentucky to central Tennessee; thence south and west to near central northern Mississippi, and southwest to central southern Louisiana; from this point the line

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[1] All inquiries addressed to this Department relating to the matter of insect pests should be directed to the Chief of the Bureau of Entomology, and those regarding diseases to the Pathologist in Charge of Fruit-Disease Investigations, Bureau of Plant Industry.

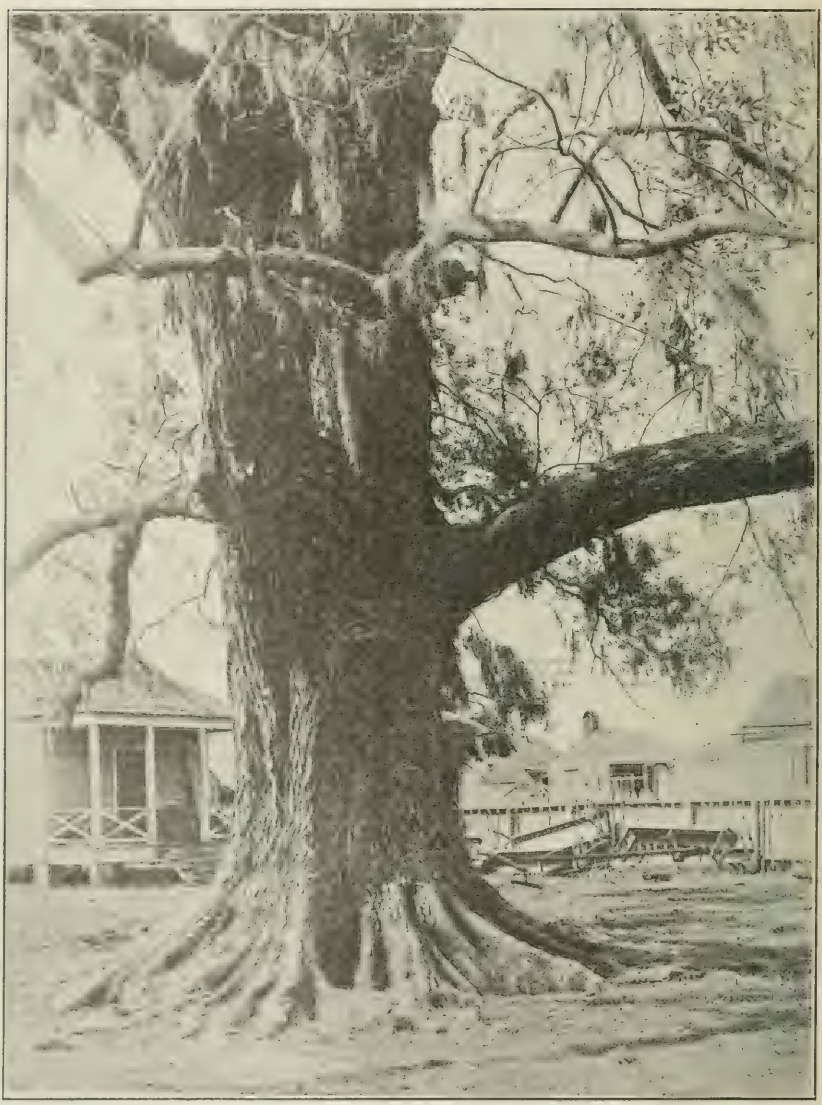

FIG. 2.—A large pecan tree in Ascension Parish, La., having an estimated height of 130 feet, a spread of 125 feet, and measuring 18 feet 3 inches in circumference at breast height.

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[1] Mohr, M. C. Garden and Forest, vol. 6, p. 373.

parallels the border of the Gulf of Mexico to southern Texas without reaching the coast. In a line nearly parallel to that of the eastern border, the western boundary extends from southwestern Iowa across eastern Kansas, western Oklahoma, and western Texas to the Rio Grande.

HABIT OF GROWTH.

In habit of growth the pecan varies greatly, according to environment and locality. Under the most favorable conditions it develops a massive spreading top in the open, while in thickly crowded forests it attains great height. In the alluvial lands of the Mississippi River bottoms specimen trees ranging from 4 to 6 feet in diameter and from 150 to 170 feet in height are not uncommon. Figure 2 shows a pecan tree in Ascension Parish, La., photographed in 1909, having an estimated height of 130 feet, a spread of 125 feet, and measuring 18 feet 3 inches in circumference at breast height. A view of a native forest cleared of all timber other than pecan, situated on the Kentucky side of the Ohio River not far from Evansville, Ind., is shown in figure 3. Pecan trees having diameters of 2 to 4 feet and heights of 75 to 100 feet are not uncommon in this forest.

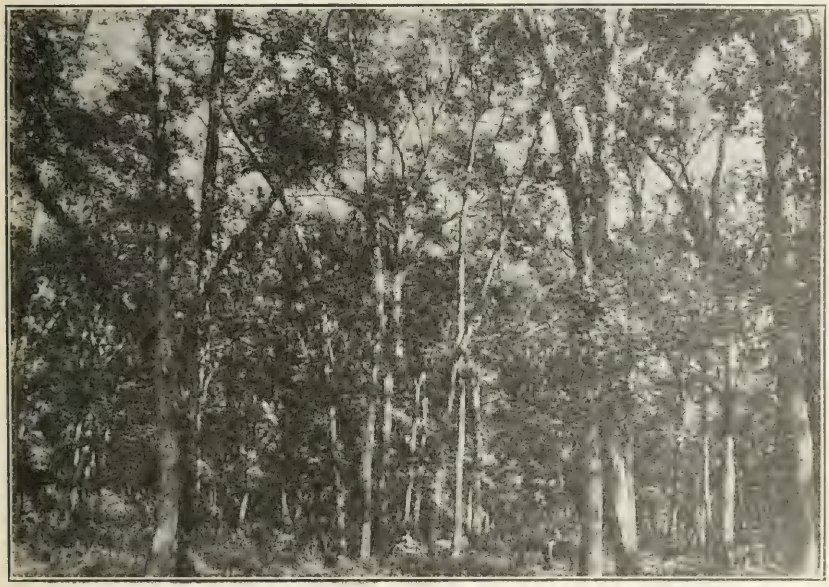

FIG. 3.—A native forest cleared of timber other than pecan on the Kentucky side of the Ohio River, 10 miles from Evansville, Ind.

In the semiarid sections of Texas the growth is different from that of humid regions; the trees do not attain such great size, their bodies are shorter, the limbs more irregular, and the terminal branches much more willowy. An illustration of the characteristic growth in that section is shown in figure 4, reproduced from a photograph taken in Landa Park, New Braunfels, Comal Co., Tex.[1]

FLOWERING HABIT.

The pecan tree has alternate pinnate leaves, with from 11 to 17 leaflets each; the flowers are monœcious, i. e., the staminate and pistillate blossoms are borne separately upon the same tree. The staminate blossoms appear in clusters of catkins upon the last season's growth somewhat in advance of the pistillate blossoms, which are found only at the terminals of the new branches. A cluster of pecan foliage illustrated in figure 5[2] shows the arrangement of floral organs. The catkins are to be seen as pendulous clusters suspended from the growth of the past season. The pistillate flowers are somewhat obscurely shown at the point of termination of the new growth. A section of a catkin is shown at *a* and of a pistillate flower at *b*, both greatly enlarged.

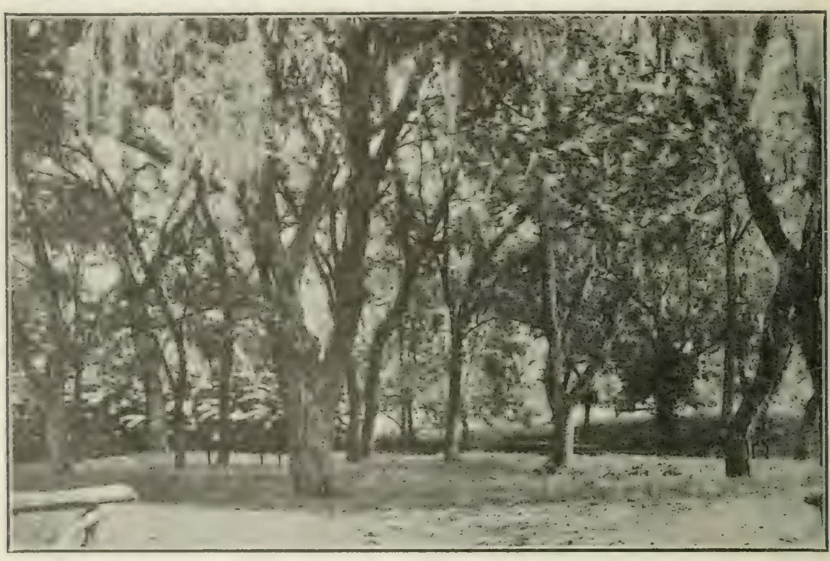

FIG. 4.—Characteristic pecan trees of Texas. Photographed in Landa Park, New Braunfels, Tex., 1910.

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[1] These trees are draped with "Spanish moss" (*Dendropogon usneoides*), a pendulous, beardlike air plant of gray color which attaches itself to the branches of many species of trees in the South. This moss is not a true parasite, as it obtains no food from its host; but if neglected after it has established itself on pecan trees it is liable to become a serious pest, as it covers the branches to such an extent as effectively to smother the bearing area.

[2] The drawing was made very early in the growing season, before the normal number of leaflets had appeared. The staminate bloom is in somewhat greater profusion than the average for the variety shown, which is the Van Deman.

DECREASE IN NUMBER OF NATIVE TREES.

The normal clearing of forests in any community during its agricultural development, the increased use of pecan timber for hardwood manufacturing purposes, and the extravagant habits of cutting out the tops at harvest time and of chopping down the trees altogether in order more easily to obtain the nuts, practices which prevail in many sections, have combined seriously to reduce the number of pecan trees in the native forests. The first two causes can hardly be prevented, and it is doubtful whether the latter practices can be checked until the finest specimens have entirely disappeared.

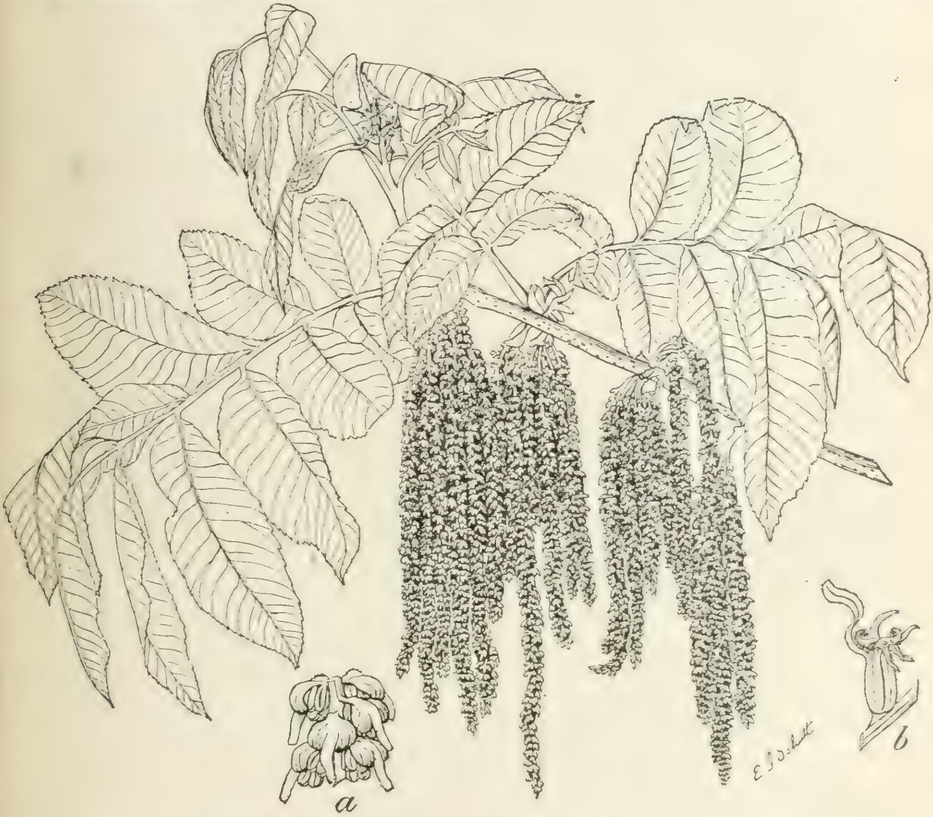

FIG. 5.—Pecan foliage and flowers. *a,* Section of a catkin (staminate flower cluster); *b,* pistillate flower.

CULTURAL DISTRIBUTION.

East of the Mississippi River and its northern tributaries the pecan has been introduced into a majority of those States to which it is not native, but it is only within certain localities that the species has thus far indicated its probable commercial adaptability. With the exception of the native trees occurring in western Kentucky, southern Indiana, southern Illinois, southeastern Iowa, and eastern Missouri, pecan trees are not found in considerable numbers north of the latitude of lower Virginia. It does not adapt itself to mountainous sections or to lowlands in which standing water is found on or near the surface for protracted periods. Few plantings have been made below central Florida or in mountainous areas, but with these exceptions representatives of the species are not uncommon over any large area in the southeastern quarter of the United States. Certain localities are undoubtedly better adapted to pecan culture than others, but in the present infancy of the pecan industry it is too early to name the most favorable sections. Orchards already planted are mostly found within a few comparatively small areas, a fact which is without doubt largely due to the common tendency of a community to follow a leader, which in this instance has been in the matter of planting pecan trees, rather than to established proof of special adaptability of the particular locality. The areas of most extensive plantings are indicated by the gradations in shading shown on the outline map (fig. 1).

EXTENT OF PLANTING.

During the winter of 1908 an inquiry was made by the Bureau of Plant Industry regarding the pecan orchards then in existence. Replies were received covering about 600 orchards situated in various portions of the South. These reports show a total of nearly 300,000 trees then under cultivation. More than two-thirds of these trees, viz, 209,069, were of named varieties (including both nursery-grown and top-worked trees), 39,839 were seedlings of known parentage, and 45,086 were from seed of unknown origin.

Of the named varieties, 175,126, or nearly seven-eighths of the total number reported, were located in 10 States, as shown in Table I.

TABLE I.—*Distribution of plantings of named varieties of pecan trees in different States.*

State.	Number.	State.	Number.	State.	Number.
Florida	48,475	Alabama	20,694	North Carolina	966
Georgia	32,990	Texas	12,894	Oklahoma	908
Louisiana	27,507	South Carolina	2,957		
Mississippi	25,449	Virginia	2,286	Total	175,126

While these figures do not cover the whole area then devoted to pecan culture, they probably indicate the proportional planting in each State.

It has been recently estimated [1] that approximately 1,400,000 trees have been sold from the nurseries during the past five years, or from the season of 1906–7 up to and including that of 1910–11. These sales appear to have been distributed among the principal pecan-growing States in much the same proportion indicated by the figures in Table I.

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[1] Letters from leading nurserymen received during February and March, 1911.

ECONOMIC IMPORTANCE.

The figures of pecan production of the census for 1910 have not yet been published, but from estimates[1] made by a number of the leading wholesalers of pecans the annual crop in the State of Texas alone during the past five years has ranged from 135 to 660 carloads, or from 3,645,000 to 17,820,000 pounds.[2] The prices to the producer have ranged from 4 to 16 cents per pound. During the past five years the average midseason price has been from 7 to 9 cents a pound. Estimates derived from the same source indicate that, beginning with Louisiana, next to Texas in quantity of production, and ending with Indiana and Illinois, each producing about 10 cars, the remainder of the average crop is apportioned among the other pecan-producing States in about the following order: Louisiana, Oklahoma, Arkansas, Kansas, Missouri, Kentucky, Tennessee, Mississippi, Indiana, and Illinois.

Commercially speaking, orchard-grown pecans have not yet been produced in sufficient quantities to affect the general market to an appreciable degree. The demand for pecans of the named varieties created by nurserymen for use as samples, or by fancy confectioners, tourists, and occasionally by seedsmen has caused a very wide range in prices, which can not be expected to reach a normal basis until the cultivated pecans reach the general markets in sufficient quantity to compete fairly with wild nuts.

Among the nuts exported from this country the pecan is of relatively small importance and is not separately listed in the Government reports. According to the annual reports of the Department of Commerce and Labor, the importations of pecans from Mexico, first separately listed in 1908, are shown in Table II.

TABLE II.—*Importations of pecans from Mexico into the United States for the fiscal years 1908 to 1911, inclusive.*[3]

Fiscal years, ended June 30.	Quantity.	Value.
	Pounds.	
1908	1,118,071	$82,181
1909	1,480,289	106,298
1910	3,349,460	232,590
1911	2,333,087	158,312

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[1] Letters received during the month of February, 1911.

[2] A carload of pecans weighs from 24,000 to 35,000 pounds.

[3] A duty of 1 cent a pound has been levied upon all pecans thus far imported.

CULTURE.

PRESERVATION OF NUT-BEARING FORESTS.

The value of pecan-producing forests is coming to be recognized to such an extent that at the present time certain enterprising owners are not only taking steps to prevent their further destruction but are increasing their productiveness by a careful and systematic elimination of all unprofitable trees, so as to give greater advantage to such as produce superior nuts.

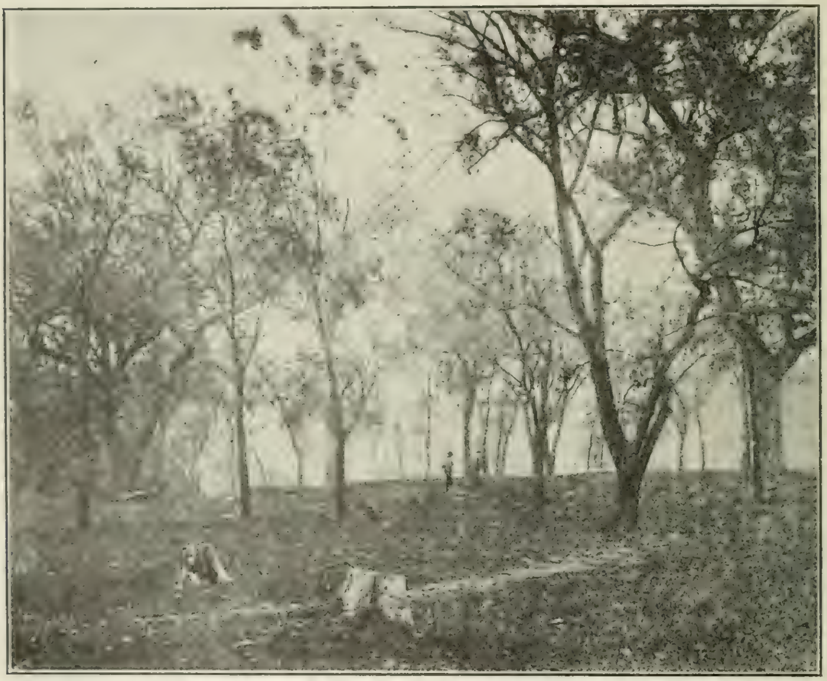

Fig. 6.—A pecan forest near San Antonio, Tex., in process of transformation into a grove by the elimination of all trees other than the most desirable pecans. Note the distances between trees.

This work is well worthy of encouragement. As clearing too suddenly will expose the remaining trees to injury by high winds, the thinning-out process should be brought about gradually. The least desirable pecan trees should be marked during the harvest period and subsequently removed. In clearing such tracts the owner should keep in mind the best methods of converting the forest into an orchard. Trees which produce the best nuts in the greatest quantity should be the ones allowed to remain. As far as possible the low-headed trees should be given preference. Pruning, having in mind the cutting back of long, spindling branches and the removal of broken tops, will have a decidedly beneficial effect. As the new tops begin to take definite form in later years, further improvement by elimination should continue. The owner must decide for himself regarding the advisability of top-working any or all trees.

When two trees of equal merit (so far as quality of nuts, regularity of bearing, health, and apparent condition of the trees are concerned) crowd each other, preference should be given the one which releases its nuts from the hulls with the greater readiness. If one is more subject to fungous diseases or to ravages of insect pests than the other, it should be removed. Vacant spaces in the wood lot should be filled in by planting nuts from the best trees or, better still, by transplanting. Any attention to cultivation, irrigation if necessary, or the application of compost should result in an increased production of nuts. A pecan forest near San Antonio, Tex., treated in the manner just described, illustrating what can be done, is shown in figure 6.

SOIL AND MOISTURE REQUIREMENTS.

In its early history the pecan was thought to be severely exacting in its requirements of soil and moisture conditions and in the essentials for successful propagation. Since becoming better known, however, it has been found that while certain conditions may be most conducive to good results, the pecan adapts itself to varying environment to such an extent that it has been planted with apparent success in a great variety of soils in the Southern States. Ideals are constantly changing as experience is gained, but in the light of present knowledge a deep, fertile soil, sufficiently porous to admit of free root growth, well drained yet by no means dry, is considered as being best adapted to pecan culture. Localities in which the water table below the surface is within reach of the taproot seem to be preferred by the pecan. This fact is of such common belief with the well drivers of the semiarid portion of Texas that they seek proximity to pecan trees when boring for water. It is essential that the trees should not be allowed to remain in standing water for any great length of time, although an occasional overflow to a depth of several feet apparently does no harm.

HISTORY OF PROPAGATION AND PLANTING.

Less attention has been paid to planting the pecan in orchard form in regions where it abounds as a forest tree than in many of the neighboring localities of nearly similar soil and climatic conditions. It seems to have been understood by certain pecan-growing pioneers previous to 1850 that the species did not come true from seed, but that information was not general until a half century later.

Practically all pecan orchards planted were of seedling trees. History[1] records that in 1846 or 1847 a slave gardener. Antoine by name, instructed by his owner, Telesphore J. Roman, succeeded in grafting 16 trees of the variety which later came to be known as Centennial. Subsequently 110 trees were similarly propagated by the same individual, bringing the total number known to have been grafted before the close of the Civil War (1865) to 126.

There is little evidence of further propagation by this method until 1877,[2] when Emil Bourgeois, of Union, La., successfully grafted 11 scions of the variety now well known as Van Deman, but then called the "Duminie" or "Duminie Mire," in honor of its owner. The Frotscher and Rome varieties were propagated by Richard Frotscher, of New Orleans, in 1882, as was the Stuart by the late A. G. Delmas, of Pascagoula (formerly Scranton), Miss., in 1886. Aside from these records there is little in pecan history to indicate that much was accomplished in the way of propagating the species other than by planting the seed until the early nineties, when grafting of named varieties came to be a matter of common practice with certain growers in southern Mississippi, Louisiana, and Texas. The limited number of superior parent trees from which to obtain grafting wood, the small degree of success then obtained with that method of propagation, the consequent high prices of nursery trees, together with the ignorance and doubt in the public mind regarding the certainty of grafted trees, resulted in the continued planting of nongrafted trees for the next decade. During the years 1900 to 1905 the fact of the very great dissatisfaction so certain to result from the planting of seedling trees came to be well known, and since then few trees of nongrafted stock have been planted.

PROPAGATION.

SELECTING SEED FOR PLANTING.

Until comparatively recent years very little attention has been paid to the selection of seed for nursery planting other than to obtain cheap nuts of high germinating quality. No thought has been given at the time of selecting the seed to the subsequent growth of the trees, and as a result there has been a conspicuous lack of uniformity in the rapidity of growth both in the nursery and in the orchard. While no one has compared the later behavior of trees which grew slowly in the nursery, when transferred from the nursery to the orchard, with the behavior of those which grew more rapidly as seedlings, it is logical to suppose that the degree of vigor is proportionately the same. It is generally conceded by nurserymen in north Florida and in south Georgia, where by far the greater portion of all nursery pecan trees are grown, and by certain nurserymen in Louisiana who are known to have made the comparison, that pecan seed from Louisiana germinates more slowly and makes slower growth than does seed from the East. For this reason Florida and Georgia seed is commonly used by southern nurserymen.

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[1] Yearbook, U. S. Dept. of Agriculture, for 1904, p. 407.

[2] Yearbook, U. S. Dept. of Agriculture, for 1904, p. 415.

Recent experience in north Florida and south Georgia in the South and in lower Virginia farther north has convinced the nurserymen in those localities that southern seedlings are undesirable as stocks for northern scions, and vice versa, in that, owing to the difference in time of starting in the spring and maturing in the fall, neither of the two makes a satisfactory growth when grafted or budded on the other.

Experience shows that for seed purposes plump nuts of medium size should be selected from vigorous-growing and productive trees as nearly free from disease as it is possible to obtain. As already indicated, it is also evident that seed from north Florida and south Georgia is preferable for use in the Gulf Coast States from Florida to Louisiana and that in the selection of seed for any locality the influence of latitude should be kept in mind.

STRATIFYING PECAN SEED.

Pecan nuts to be planted as seed should be retained in as nearly as possible their original condition at the time of harvest. If allowed to become dry they should be thoroughly soaked before planting. If the nuts are to be held for a period of several weeks or during the fall and winter for spring planting they should be stratified as soon as practicable after harvesting. "Stratification" is the technical term for the method of packing the nuts in moist sand and keeping in a cool, dark place to prevent evaporation or germination by combined warmth and moisture. To protect the nuts from rodents, the box or boxes in which the nuts are kept should be covered with wire screen. Proper drainage must be assured.

PLANTING PECAN SEED.

The planting of pecan seed may be performed soon after harvest or early in the spring. Fall planting does away with the need of stratifying, but encounters the risk of loss by winter injury and depredations of field mice and other rodents.

Germination is earlier and growth quicker in sandy soils than in heavy soils. Proper drainage is also more easily assured in sandy soils, and for these reasons light soils are ordinarily preferred for nursery purposes. Irrespective of its nature, the land should be thoroughly prepared before the seed is planted. The soil should be fertile, well cultivated, and yet firm. Plant the nuts 2 to 3 inches deep and 8 to 12 inches apart in rows 4 to 6 feet apart; cover with loose, fertile soil, and pack firmly. A top-dressing of leaf mold or other light compost 1 or 2 inches deep will aid greatly in keeping the surface mellow and moist.

During the first season the growth will be largely confined to the development of a taproot, which will be from 3 to 5 times the length of the top. In ordinary seasons the growth above ground will be from 6 to 12 inches.

A method occasionally followed is to plant half a dozen nuts in the permanent location where the tree is to stand. Later the best one of the resulting trees is grafted with the desired variety, and the others are cut away. This method avoids the labor and expense of transplanting. In actual practice, however, this method has thus far rarely proved satisfactory. On the contrary, the claim is made by several of the more experienced growers that transplanting pecan trees results in more compact and fibrous root systems and is therefore a positive advantage. Unless protected by heavy stakes, the young trees under these conditions are subject to injury by careless workmen. Moreover, it frequently happens that none of the nuts planted produces a tree fit for grafting. It is therefore doubtful whether this method of establishing an orchard can be commended.

COMPARISON OF SEEDLING AND GRAFTED TREES.

As has been previously explained, no matter how carefully the seed may be selected, pecans grown from the nuts do not reproduce themselves true to the parent type. Of all the trees observed in past experience with the pecan not a single authentic instance is on record in which a tree grown from the nut has been identical with its parent or any of its sister seedlings. Whenever it is desired to perpetuate definite varietal characteristics of the pecan it must be done by asexual methods of propagation, i. e., by grafting or budding. In contradiction to this, certain tree dealers have recently advanced the claim that grafted and budded trees are proving unsatisfactory, asserting that they are shorter lived and more subject to disease than seedlings; that they are otherwise objectionable and are consequently being discarded. Evidence to support the claim that the operation of either grafting or budding, when successfully performed, has any effect whatever upon the longevity of the tree or its susceptibility to disease is entirely lacking. Healthy grafted and budded trees of all ages up to 30 years since the operation was performed are sufficiently common throughout the pecan area entirely to dispel all doubt as to the enduring qualities of trees so propagated. Statements to the opposite effect are made evidently for the sole purpose of selling inferior seedling trees.

As ordinarily only such sorts as are especially productive or otherwise superior to the average are commonly perpetuated by asexual propagation, a belief has become more or less prevalent that in some way the operation in itself is responsible for the productiveness. This is a mistaken view, as the scions and buds only perpetuate such characteristics as they inherit from the parent tree. Wood of the previous season is preferable for grafting and should be taken only from the very best and most carefully selected parent trees.

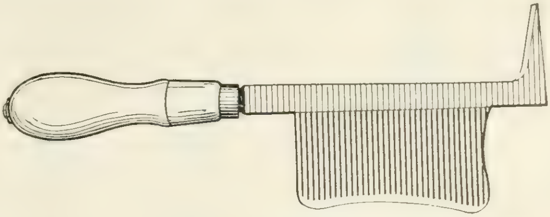

Fig. 7.—A tool especially designed for cleft grafting.

CLEFT GRAFTING.

In its modifications grafting has been longer employed than budding. It is performed during the late winter months just as the buds begin to swell, or very early in the growing period. At that time the upward flow of sap is most rapid and the union will be accomplished most quickly. Scions for any kind of grafting should be selected from the growth of the last season. Terminal twigs were formerly used almost exclusively and are still preferred by some propagators. But, as the bud at the end of the branch rarely produces a strong shoot, ordinarily drying up and falling off instead, terminal twigs are no longer used to a large extent.

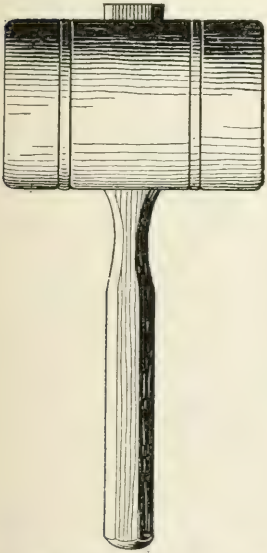

Fig. 8.—Mallet for use in cleft grafting.

A well-filed fine-tooth saw, a sharp grafting knife, a specially devised grafting tool (fig. 7), a short-handled wooden mallet (fig. 8), a quantity of raffia and grafting wax or grafting cloth, and a number of scions constitute the necessary equipment for grafting. In performing the operation of cleft grafting, the trunk or limb of the tree to be grafted (technically known as the stock) should be cut squarely across with the saw; the knife edge of the grafting tool should then be placed across the stock, either over the center or to one side in order to avoid the pith, and by tapping the back of the tool with the mallet split or, better, cut the stock to a depth of 2 to 4 inches. Remove the tool and pry the two parts of the stock apart with the thick, narrow wedge projecting from the back of the graft-

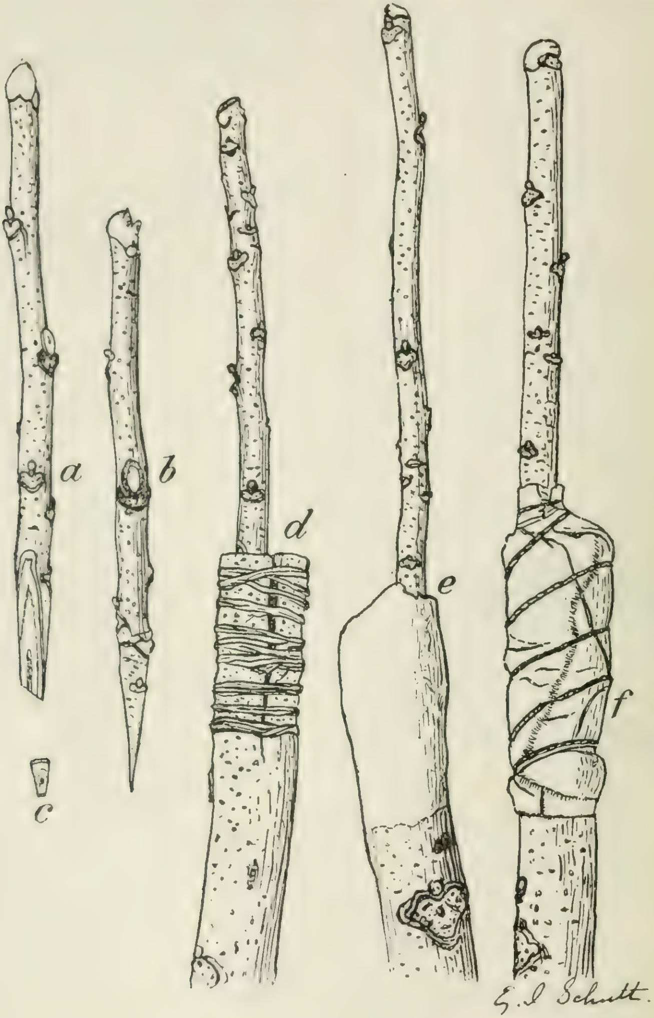

Fig. 9.—Cleft grafting. Successive steps in the operation: *a* and *b*, Views of the scion; *c*, cross section of the scion, thicker on one side; *d*, the scion in place and the stock securely tied to prevent splitting; *e*, the union covered with grafting wax; *f*, outer wrapping securely held with string.

ing tool at the extreme end. Prepare the scion by sharpening its lower end with the grafting knife into the form of a wedge (fig. 9, *a* and *b*) made thicker on the side which will be outermost when in position (fig. 9, *c*). Insert the wedge end of the scion in the cleft of the stock so that the cambium layer (inner bark) of its thick side will be in close contact with the inner bark of the stock. The scion should be pushed into the cleft until the cut surface of the stock is on a level with the base of the first bud. It will do no harm if it goes slightly deeper. It is imperative that the two cambium layers be brought together as closely as possible. With stocks of sufficient size a second scion may be similarly placed in the opposite end of the cleft. Remove the iron wedge from the middle of the cleft and cover the cut surfaces, including the tip of the scions (unless terminal shoots have been used), with grafting wax especially prepared, being careful not to cover the buds. If the stock is weak and inclined to further splitting after the wedge has been removed it should be tightly wound with several wraps of a stout, rather coarse material before the wax is applied. Where a large amount of grafting is to be done, the best as well as the cheapest material for wrapping is a product of one of the eastern tropical palms, known as raffia, which is obtainable from dealers in nursery supplies. For propagation on a small scale, cotton warp, strips of old muslin, or similar material will answer fully as well.

FORMULAS FOR GRAFTING WAX.

(1) Mix together thoroughly 4 parts (by weight) rosin, 2 parts beeswax, and 1 part tallow.

(2) A harder wax for use in warm weather is made of the following: Rosin, 4 pounds; beeswax, 1 pound; raw linseed oil, one-half to 1 pint.

To prepare either formula melt the ingredients together, pour into water, and pull. Rub the hands with oil or grease before using to prevent sticking. In using the second formula the proportion of oil will depend upon the season, a greater quantity being necessary in cooler weather.

PREPARATION OF GRAFTING CLOTH.

Thin calico or cheap muslin saturated in melted wax, drained, and allowed to cool makes a material which answers both as a wax and as a binding substance. Before immersing in the liquid, tear the cloth into strips 12 to 18 inches wide or of whatever width may be most convenient. When thoroughly saturated take it from the solution and while still warm remove the excess of hot wax. Various methods of accomplishing this removal are practiced. On a small scale the cloth may be wrung out with the hands, but when larger quantities of material are to be made a convenient method much in use is to draw the cloth between two flat pieces of wood. A simple method is certain to suggest itself to any ingenious operator.

When grafting cloth of the proper consistency is used raffia will be unnecessary, as the properly prepared material carefully wrapped holds itself in place without being tied.

CARE OF CLEFT GRAFTS.

Obviously, two scions placed in one cleft double the chance of success. With an ordinary wrapping of waxed cloth further attention to the graft itself will not be needed. If wound with stout material the bandages should be severed as soon as growth has begun, when the weaker of the two scions should be cut away. If both scions are allowed to remain, the formation of a fork between the two will be inevitable and splitting very apt to follow. A single scion affords a much better opportunity for the development of a symmetrical head and there is less danger of crowding than when two scions are left.

WHIP GRAFTING.

The operation of whip grafting is usually performed during the latter part of the dormant season, at any point in the trunk from immediately below the surface to several inches underground. For this method of propagation the stock and the scion should be of very nearly the same size, preferably not more than three-fourths of an inch in diameter nor smaller than a lead pencil. With the knife held so as to make an upward incision, cut the stock entirely across at a long angle, as shown at 1 in figure 10. At about one-third the distance from the upper end of the cut make an incision parallel with the grain, as shown at 2 (fig. 10). Cut the scion at as nearly the same angle as possible and make a similar incision in the cut surface one-third the distance from the upper end of the cut, as shown at 3 (fig. 10). Push the cut surfaces together in such a way that the tongue of the scion made by the incision will be crowded into the groove made by the incision in the stock, as shown at 4 (fig. 10). Bind the two parts together with raffia or other material, as shown in figure 11 at *a* (not as appears at *b*), and pack firmly with earth. The use of wax is not necessary.

CARE OF WHIP GRAFTS.

When grafted by the whip-graft method the young trees will require little subsequent attention other than pruning and ordinary cultivation. When the root is that of a very young tree there will be no danger of the supply of plant food being such as to induce a growth of top that is too rapid, as is frequently the case with cleft grafts, especially in the tops of old trees. While temporary staking as a support to the union is not necessary, in numerous cases stakes will be highly essential to insure erect growth. The moisture of the ground causes the wrapping material to decay in the course of a few weeks, and it is therefore not necessary to cut the bands, as with cleft grafts.

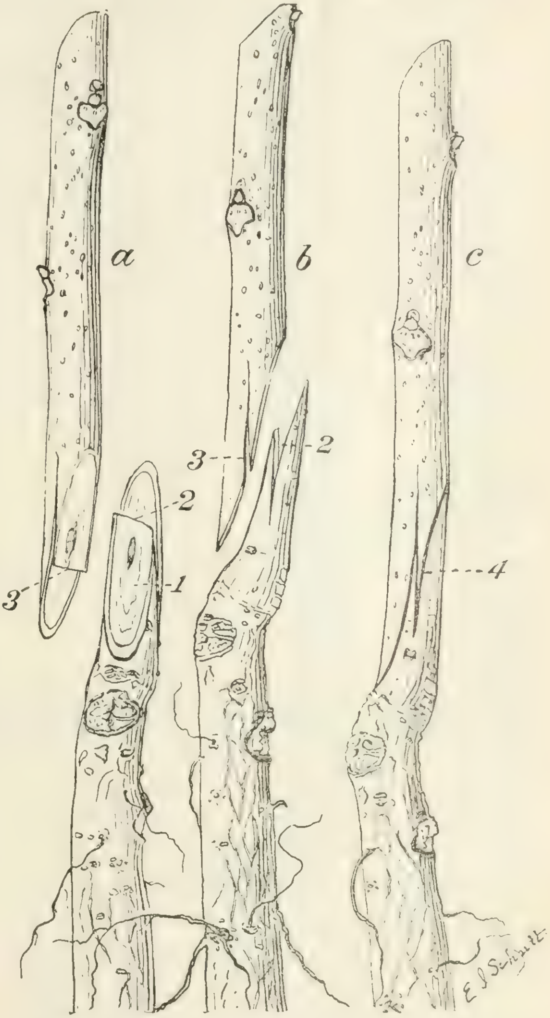

FIG. 10. —Whip grafting. Early steps in the operation: *a* and *b*, Front and side views of both stock and scion properly cut; *c*, stock and scion in position and ready for wrapping.

BUDDING BY THE ANNULAR METHOD.

It is probable that more pecan trees have been propagated by annular budding, with its modifications, than by all other asexual methods combined. The process is also known as "ring" and "flute" budding. It is performed during the midsummer months at such time as the bark is found to slip (release) most readily. In some seasons this period may be very brief, lasting only a few days, while in other years the time during which annular budding may be successfully performed extends over a period of several months. In the latitude of southern Georgia it is not uncommon for this method to be successful from as early as May 10 until late in July or even in August.

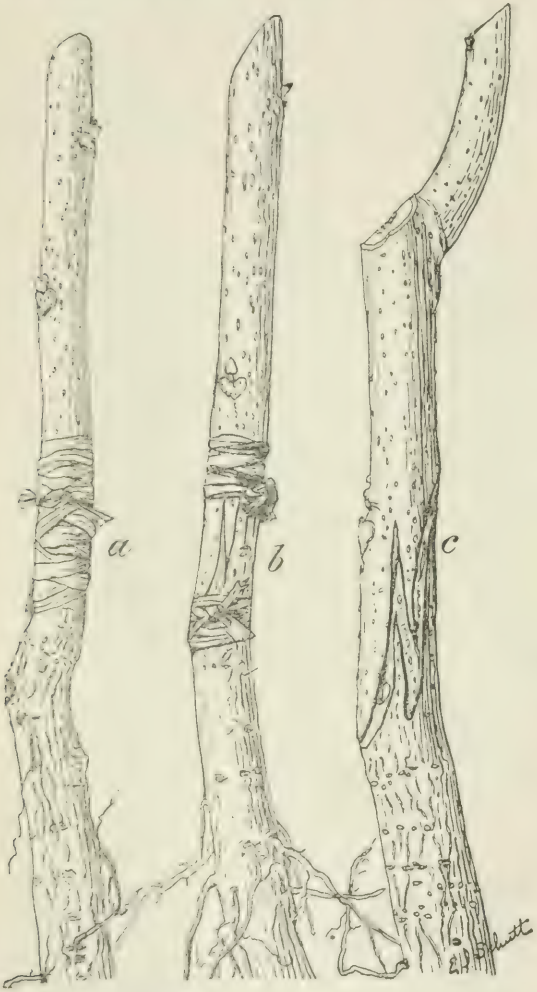

FIG. 11.—Whip grafting. Later steps in the operation: *a*, Proper method of tying; *b*, improper method of tying; *c*, one year's growth following a successful union.

Annular budding consists merely in transferring a ring of bark to which is attached a bud of the desired variety from a bud stick[1] to the trunk or branch of another tree in place of a similar ring of bark previously removed. Specially designed tools, such as are shown in figures 12, 13, and 14, have been devised for the purpose of cutting the rings. Two ordinary propagating knives having single blades may be fastened together and made to answer the purpose, although they are less liable to make uniform incisions. Cut a ring of bark from the stock with one of the tools, slit it with a single-bladed knife, and lift from its bed or "matrix," as it is technically called. Discard this bark and from the bud stick remove a similar ring, in the center of which is a dormant bud. The bark of the bud stick should be slit on the side opposite the bud. Immediately place this ring in the space left by removing the bark from the stock and wrap at once with waxed cloth, taking care not to cover the bud (fig. 15).

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[1] The bud stick is a branch, usually about 2 feet in length, cut from a tree of the variety to be propagated.

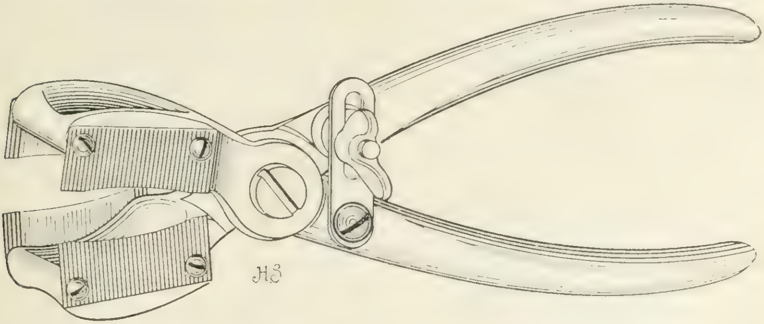

FIG. 12.—A metal tool specially designed for use in annular budding.

BUDDING BY THE PATCH METHOD.

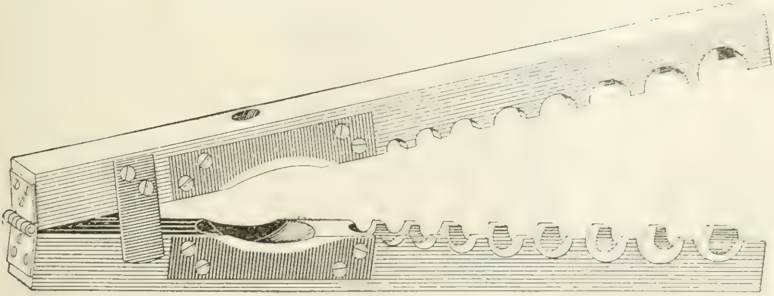

FIG. 13.—A tool with wooden handles and steel blades specially designed for use in annular budding.

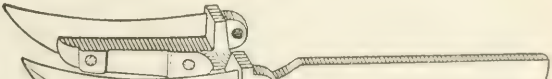

FIG. 14.—Another type of metal tool specially designed for use in annular budding.

When the annular method is used it is obvious that the stock and scion must be of nearly the same size. If the bud stick is slightly larger than the stock a portion of the bark to which the bud is attached may be cut away so that the two ends of the ring just meet around the stock. If the bud stick should be smaller than the stock a strip of bark on the latter may be left in position to complete the ring. In actual practice, rings which extend only partly around the stock are most commonly used. Such process, however, is not true annular budding, because any bark which extends only partly around the stock is merely a patch. It is to this deviation from the annular method of budding that the term "patch budding" has been applied. A tool specially designed for patch budding is illustrated in figure 16. It consists of four thin steel blades fastened together in the form of a rectangle, five-eighths of an inch wide by 1 inch long, and is used as a punch.

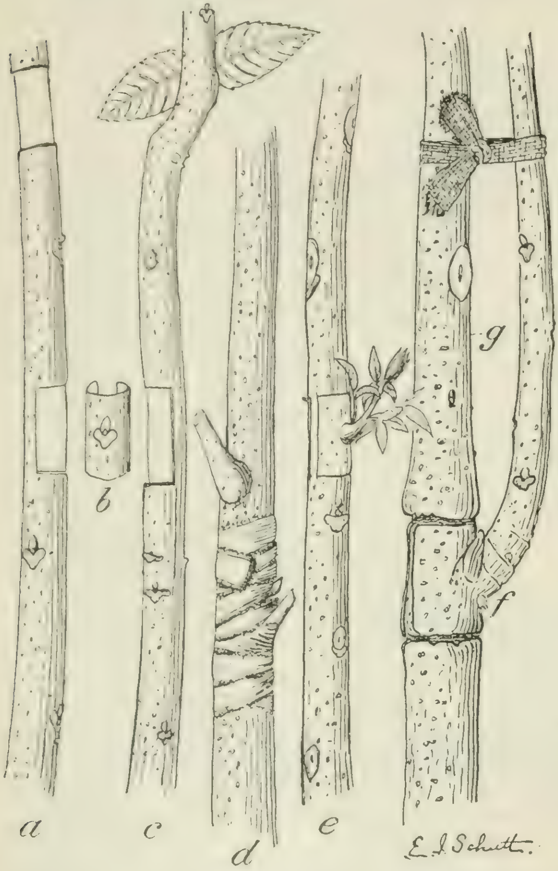

FIG. 15.—Annular budding. *a*, Bud stick from which the the bud has been removed; *b*, the bud ready for insertion in the matrix of the stock; *c*, the stock ready to receive the bud; *d*, the bud after being placed in position and carefully wrapped; *e*, growth taking place, the wrapping having been removed; *f*, growth from the bud supported by being tied to the stock (*g*) above the union. Note the scars above the union, where the buds were removed in order to direct the flow of sap to the new bud.

A very fair degree of success in patch budding by using an ordinary single-bladed budding knife is reported from Texas. A cut is made in the bark of the bud stick about half an inch in width by three times as long, in the center of which is the bud. The piece of bark so outlined is removed from the bud stick and laid over that of the stock. Using this as a pattern, incisions are then made around it in the bark of the stock. The pattern is then removed, the section of bark outlined in the stock is lifted, and the bark from the bud stick is put in its place. Some varieties of the pecan are more difficult to bud successfully than others; with such varieties the annular method, or a near approach to it, is generally most successful.

With the average sorts, however, the tendency among the more experienced nurserymen is much inclined to favor the patch method, which may be performed with any of the tools illustrated in figures 12, 13, 14, and 16.

The buds best suited to annular or patch budding are those in the axils of the leaves at the base of the current season's growth. It is well worth the time required to clip the leaves away, close to the buds, 10 days or 2 weeks before the bud is wanted, for by so doing the wound will heal over before the bud is needed; otherwise a serious lessening of the vigor of the bud through evaporation may take place.

CARE OF ANNULAR AND PATCH BUDS.

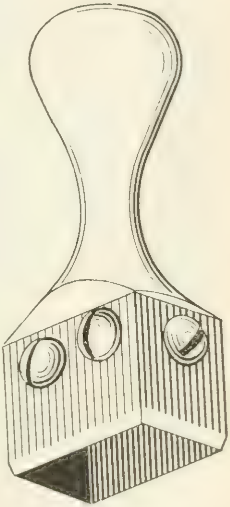

FIG. 16.—A metal tool specially designed for use in patch budding.

In annular budding the added ring of bark sometimes unites with the stock promptly, permitting the upward flow of sap to proceed without much interference. When this is the case the top should be carefully pruned back to such a degree as is necessary to direct sufficient sap into the new bud to cause it to swell. This pruning should not be done with too great severity, as an oversupply of sap is liable to accumulate under the bark of the new bud and cause it to decay or, as it is termed, "to drown" the bud. If the tree is young and the growth has been rapid, precaution should be exercised in cutting back the top in order not to expose the tender bark to the heat of the sun. A sufficient amount of foliage should be left as a protection from the hot sun. If the supply of sap be limited, it will be well to cut out all buds in the top of the stock as shown in figure 15. All dormant buds, both above and below the new bud, should be rubbed off as soon as they begin to swell. The wrapping about the new bud must be cut as soon as growth begins. As the union of a bud with a stock made by any method of budding is at first merely the uniting together of bark and not of wood, it is necessarily weak during the first few months. To avoid danger of breaking out at the bud the new tops should be provided with extra support. For this purpose side stakes driven into the ground are sometimes used, but these are expensive and unnecessary. By leaving a stub of the original top 8 or 10 inches long, entirely denuded of foliage (*g*, fig. 15), the new top may be quickly tied to it, and when no longer needed the dead stub may be cut away close to the union.

BUDDING BY THE CHIP METHOD.

Propagation by chip budding is performed in the early spring or late in the dormant period. Because of being done at this season it is also known as "dormant" budding. With a sharp knife a downward cut is made below the bud on the bud stick to a depth of perhaps one-eighth of an inch. Raising the knife to a point above the bud a long downward cut is made which meets the lower end of the first cut and the bud is removed with a chip attached, as shown in figure 17. A similar chip is removed from the stock and the desired bud is put in its place. This should be carefully wrapped with such material as will hold the cambium layers of the stock and the bud firmly together on at least one side.

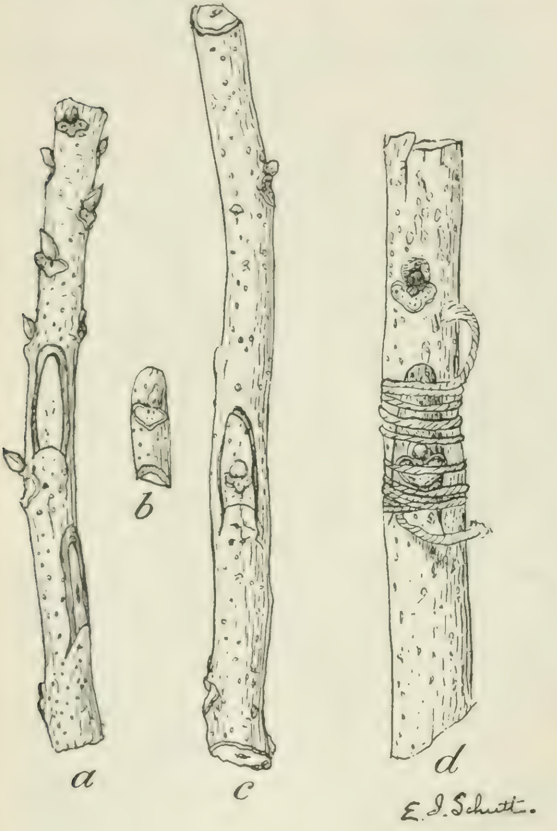

FIG. 17.—Chip or "dormant" budding. *a*, The bud stick; *b*, the bud ready for insertion; *c*, the bud inserted in the matrix of the stock; *d*, the bud securely tied in place.

Subsequent treatment similar to that already described for annular and patch budding should be given young trees propagated in this manner.

Trees of the pecan species are difficult to propagate asexually; that is, neither buds nor scions "take" with the readiness of ordinary fruit trees. The inexperienced operator, therefore, must expect a very low percentage of living buds as the result of his first attempts. Skilled propagators, however, are now so successful that under favorable conditions the percentage of failures is no longer a matter of consequence.

No attempt to bud pecans should be made on rainy days or in early mornings following heavy dews. Some nurserymen even go so far as to select their men for budding the pecan, assigning those who perspire most freely to other duties. Extremely hot days should be avoided, especially if accompanied by drying winds. Moderately cool, cloudy days without wind or rain are the best for pecan budding.

STOCKS FOR GRAFTING AND BUDDING.

LENGTH OF TIME TREES SHOULD REMAIN IN THE NURSERY.

In the Gulf Coast States seed nuts are ordinarily planted during the months of January and February. With conditions favorable for rapid growth, a majority of the young seedlings should be large enough to graft in 12 months and should be ready for transplanting by the end of the second season. If they are to be budded they should reach sufficient size for that operation by the middle of the second season or when at the age of 18 months. Another period of equal length will be required for the trees to attain the desired size for transplanting. It will thus be seen that under exceptionally favorable conditions grafted trees will be ready for planting in the orchard two years from the time of planting the seed as compared with three years for budded trees under ordinary circumstances. In actual practice, however, comparatively few trees attain sufficient size for grafting until the end of the second season; the greater amount of grafting is, therefore, performed on 2-year-old roots. In either case the age of the root is the same, whether grafted or budded, and when established in the orchard the method by which a tree was propagated becomes immaterial.

TOP-WORKING.

The importance of changing the tops of pecans and other nut or fruit trees by the top-working method can hardly be overestimated. By this method seedlings and trees of unsatisfactory varieties may be quickly transformed into bearing trees of more valuable kinds, new varieties may be hastened into bearing, untried sorts may be quickly tested in a new locality, several sorts may be tested on the same tree, and varieties grafted to uncongenial stocks may be given a new trial by being transferred to other trees. Seedling orchards scattered over the entire pecan area are already being transformed in this manner. Wild trees, both in the forest and in the open, are being similarly improved.

STOCKS FOR TOP-WORKING.

For the purpose of top-working, trees of both the pecan and the hickory species are used. Although belonging to the same botanical family as the walnut and the butternut, the pecan is of a different genus. The relationship is too distant to make the grafting of it upon stocks of either worthy of the attempt. The matter of top-grafting the hickory is discussed under another heading (p. 33).

In general, it is possible to transform the tops of pecan trees of practically any size or age by top-working; but the advisability of attempting so to transform giant trees or such as have begun to deteriorate with age is very doubtful. The operation is of chief value to healthy trees under 30 years of age.

HOW TO TOP-WORK.

The operation of top-working is begun during the dormant season. At that time little danger of killing the trees by severe pruning is incurred. With the exception of a few branches which should be left to utilize the excess of sap while the development of the new top is in progress, the top should be cut back to the point at which the new head is to begin. Commonly the lower three or four limbs are left for this purpose. In working over a large number of trees an elevated platform built at convenient height and attached to a wagon for use during the several stages of the operation will be a great convenience. If the limbs to be cut are large, wind a heavy chain about the branch immediately below the place of cutting, in order to obviate the danger of splitting. A shallow cut on the lower side will further tend to reduce this danger. Trunks more than 6 inches in diameter heal more slowly than those of smaller size; whenever practicable the larger trunks should not be cut. Figure 18 illustrates a tree properly cut back and figure 19 shows one which was cut back too severely. If desirable, the top may be cleft-grafted as soon as cut back, or new growth may be allowed to start, to be budded in midseason by whatever method may be preferred. In small trees three healthy scions or buds centrally located will be enough to insure a symmetrically formed top. As soon as the new growth reaches sufficient size to utilize the entire flow of sap the remaining branches of the original top should be removed. Figure 20 shows a 7-year-old tree which was cut back[1] in February, 1908, budded August 10 of the same season, and the lower branches of which were removed September 1, 1909. The four spurs below the branches indicate the points at which the branches were cut away. These spurs were later pruned closely during the dormant season.

Figure 21 shows a large tree near Morgan City, La., top-worked when about 25 years old and photographed six or seven years later. The points at which the operation was performed are indicated by the right-angular union more or less distinct in each branch. It is a very well-shaped tree. An objection to this method of top-working lies in the fact that the new head of the tree must be formed considerably higher than the old and there is danger that it will be too high. This is especially true with varieties such as the Stuart, Jewett, and others which are inclined to upright growth. If the original top is already high, it is generally best to cut back and graft the lower branches a year before cutting away the central part of the top. Enough of the top may be cut back at the same time to force a liberal supply of sap into the graft. The sap can not be directed to the lower limbs in this manner if the higher limbs are grafted first, for in that case pruning will be fairly certain permanently to disturb the symmetry of the new top.

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[1] Top-worked by Mr. B. W. Stone, Thomasville, Ga.

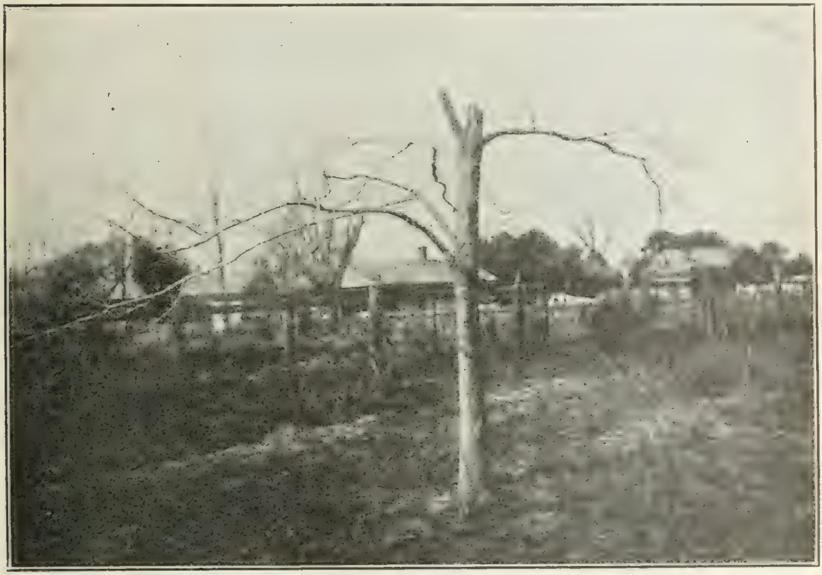

FIG. 18.—Seedling tree cut back during the dormant season to induce new growth for top budding.

TOP-WORKING HICKORY WITH PECAN.

Because of their close relationship the scions and buds of the pecan readily unite with stocks of the hickories. The advantages sought in such operations are the quick introduction of the pecan to localities to which it is not common but where hickories abound, the utilization of trees of inferior species, and the possibility of discovering a stock for the pecan which will have certain advantages over those ordinarily used. A number of species are known to have been tried; in southern Louisiana several trees of the water hickory (*Hicoria aquatica*) in standing water produced a healthy, strong pecan top, but later died outright, while others of the same species not top-worked remained alive under the same conditions; another of these trees taken up and transplanted to drier land made good growth and according to latest reports was bearing satisfactorily.

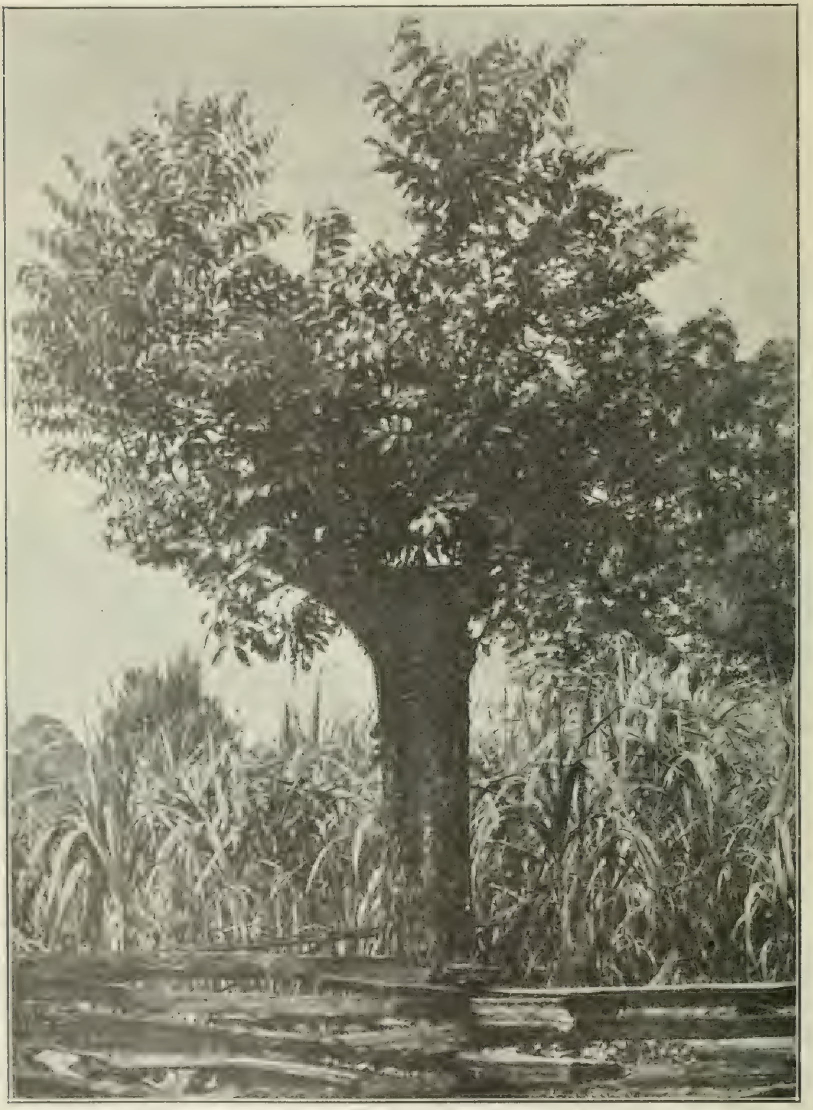

FIG. 19.—Seedling tree cut back to a stump 15 inches in diameter, for top-working. With large trees the sprouts on one side only should be budded. As large a portion of the stump as possible should be hewn away in order to allow the wound to heal.

In Florida, where the mockernut (*Hicoria alba*) is common, the pecan has been found to unite readily with it and to make a rapid growth until the diameter of the pecan becomes equal to that of the hickory, after which it grows much more slowly. Other hickories have been tried; while the early growth is generally reported to be strong and rapid, very few have thus far proved satisfactorily fruitful.

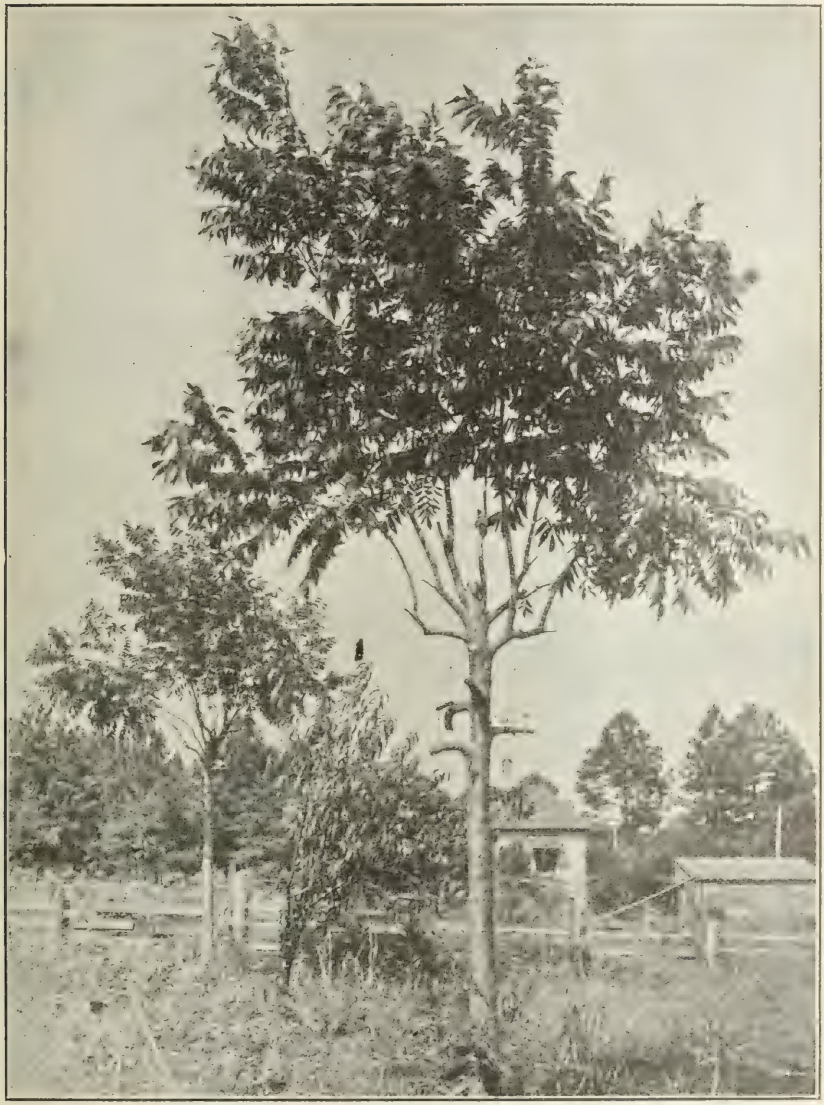

FIG. 20.—A 7-year-old pecan tree top-worked with Stuart scions. The seedling top was cut back in February, the buds were inserted August 10, and the lower branches removed September 1 of the next year. Note how the head of the tree has been elevated.

As hickory trees top-worked with pecan usually stand in out-of-the-way places, not uncommonly in wood lots, it is doubtful whether the reason for unfruitfulness is due to the influence of the hickory species or to the lack of cultivation.

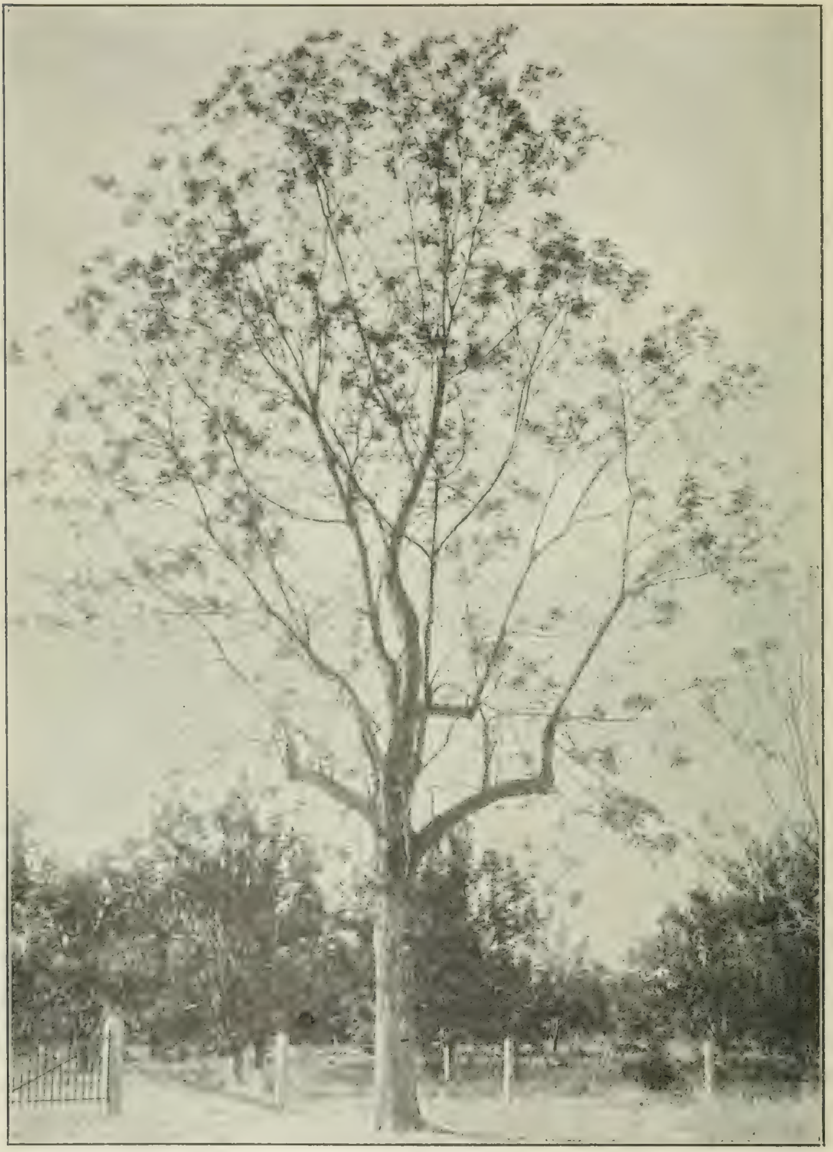

FIG. 21.—Pecan tree in Morgan City, La., top-worked when about 25 years old and photographed 6 or 7 years later. A very well-shaped tree, although headed rather high.

Department investigators have generally observed a conspicuous difference in the rapidity of growth between the hickory stock and the pecan scion. As a usual thing the pecan is the more rapid grower, as is illustrated by figure 22, which undoubtedly affords the earliest instance on record of a pecan tree[1] grafted to a hickory stock. The operation was performed 1 foot from the ground about the year 1880. The tree is now 40 or 50 feet tall and has a spread of about the same

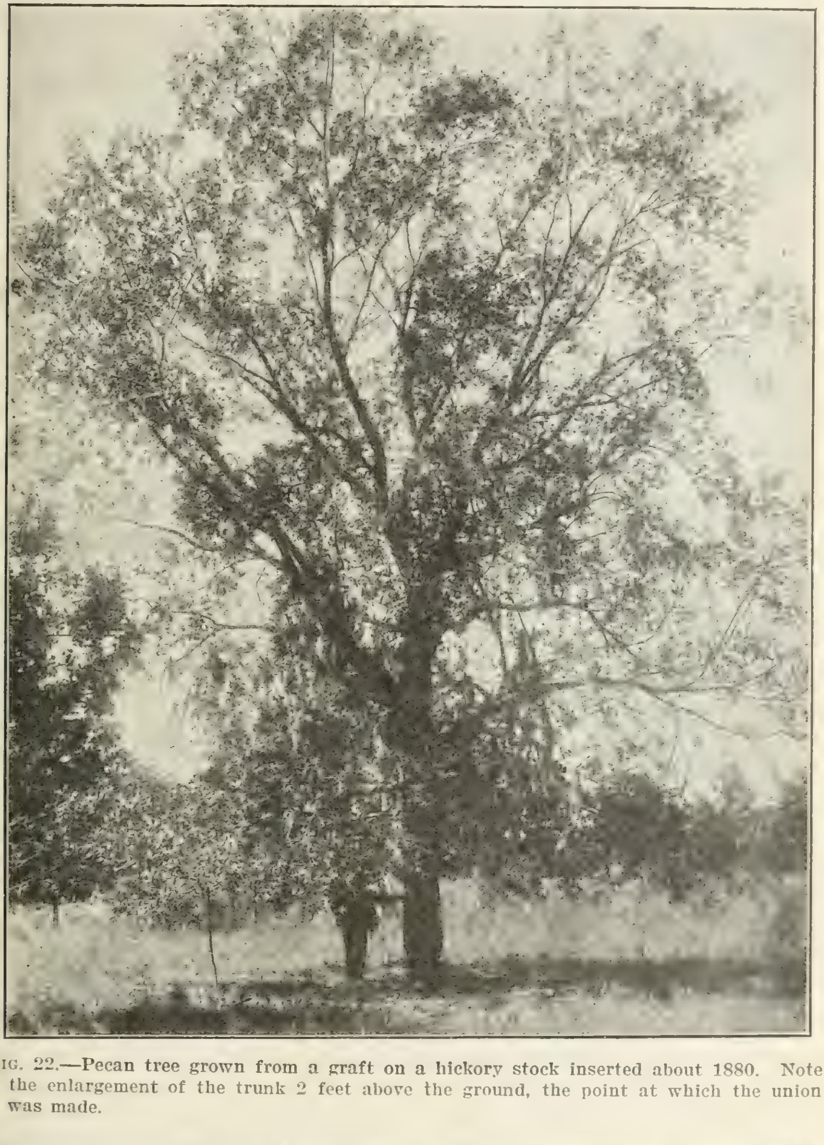

FIG. 22.—Pecan tree grown from a graft on a hickory stock inserted about 1880. Note the enlargement of the trunk 2 feet above the ground, the point at which the union was made.

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[1] Near Gainesville, Fla. Photographed in October, 1910.

distance. The trunk measured 5 feet 9½ inches in circumference below the graft, 6 feet 11 inches at the point of union, and 6 feet at breast height. It was, therefore, 1 foot 1½ inches greater in circumference at the point of union and 2½ inches greater 4 feet from the ground than the hickory trunk at the place of its greatest circumference.

Nothing is known of the source of the pecan scion, but it is not improbable that it was cut from an ordinary seedling. The bearing record of this tree is unknown, but as it stands in rather poor soil and bore no nuts during the year observed (1910), it has probably never fruited to any considerable extent.

PLANTING.

Orchard trees are ordinarily transplanted from the nursery to their permanent location during January or February. The soil should first be put in good condition by thorough cultivation and, if necessary, steps should be taken to insure proper drainage.

The usual distance for planting differs in localities. In the deep alluvial lands of Louisiana and the Mississippi Valley, where it is expected that the trees will attain greater size than when grown in the lighter soils of the more eastern States, pecans are now being set at distances varying from 50 to 75 feet. Some planters, having in mind the idea that 100 feet will be the most suitable distance when the trees reach maturity, are planting at 50 feet, with the intention of removing the alternate trees as soon as crowding begins, leaving them eventually 100 feet each way.

In Georgia, a distance of 46 feet and 8 inches each way (20 trees to the acre) was adopted for some years, but as the orchards so set approach maturity it is becoming evident that considerably greater space would have been better. These planters now agree that 60 feet apart (12 trees to the acre) is not too great a distance.

TREES FOR PLANTING.

As has been explained, nursery-grown trees are mostly planted at the age of 3 years. While sometimes sold as though graded according to age, they are actually graded according to size. If sold under the age grade the largest trees are naturally the "oldest." For this reason it is much more satisfactory to buy according to size, although in that case there is danger of slow-growing stock being worked into the lot. Within certain limits a nursery-grown pecan tree which has reached a given size in a given length of time is much to be preferred to one which has been twice as long in attaining the same size. It is natural to expect that the rapidity or slowness of growth displayed in the nursery will be relatively the same throughout the life of the tree. For this reason the healthy, quick-growing trees in the nursery are much preferable to those which grow slowly. Figure 23 shows five trees, selected to show one of each of the grades adopted by nurserymen. Beginning at the right the grades of 1 to 2 feet, 2 to 3 feet, 3 to 4 feet, 4 to 5 feet, and 5 to 7 feet are represented. These measurements are of the top only; the length of the taproot is not taken into consideration.

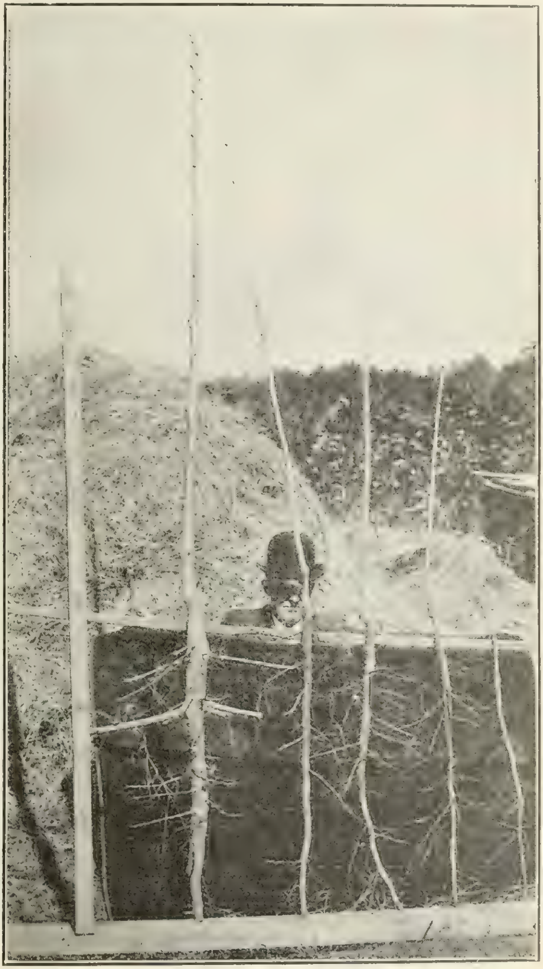

FIG. 23.—Nursery-grown pecan trees, showing the standard grades. Right to left: 1 to 2 feet, 2 to 3 feet, 3 to 4 feet, 4 to 5 feet, 5 to 7 feet. The seed from which these trees were grown was planted in January, the seedlings were whipgrafted during the month of February of the second year following, and the trees were dug in the succeeding November. The board upon which the trees are standing indicates the point at which the taproots were cut.

The taproot, which it was once thought necessary to protect in transplanting, is now cut off about 2 feet below the surface. In a nursery[1] visited during the fall of 1910, a tool specially designed for the purpose was being used in cutting off the taproot.

Purchasers of nursery stock should insist that the trees be allowed to remain in the nursery in the fall until all growth has ceased and the foliage has fallen normally. The early demand for trees has recently impelled nurserymen to dig a great portion of their trees while still in full leaf. At that season neither the top nor the root system is in a condition to be disturbed. The cutting away of foliage, branches, and roots while the sap is still in circulation results in a heavy shock which is injurious and wholly unnecessary. It is therefore highly important that every buyer of southern varieties of pecan trees grown in the South should insist that the trees be not dug until the leaves have dropped naturally, which is usually about the middle of November. With northern varieties the situation may be different, as the wood of these varieties matures very much earlier. However, with southern varieties grown in the South, it would be better for the trees not to be dug from the nursery rows before the last of November in any season.

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[1] The Monticello Nurseries, Monticello, Fla.

SETTING THE TREES.

Extreme precaution should be taken to prevent the roots from becoming dry. They should be kept carefully covered from the time they are dug until finally set. A large hole, fully twice or three times the size actually required to receive the roots, should be dug. A quantity of well-rotted compost or nitrogenous fertilizer placed in the bottom of the hole, entirely covered with earth before setting the tree, will furnish plant food during subsequent seasons and tend to induce a deep root system. Immediate contact of the roots with compost or fertilizer of any kind must be avoided. All broken parts of the roots and all lateral branches of nursery-grown trees should be pruned away. Soaking the roots in a bucket of water for an hour or two or even over night gives the trees a very great advantage. The trees should be placed in the hole at about the same depth as they grew in the nursery. Spread out the roots carefully with the hands and pack firmly with moist surface soil thoroughly pulverized. If the soil is dry, it should be drenched with water before the hole is entirely filled.

CULTIVATION.

Satisfactory tree growth and bearing qualities can be expected only in return for careful attention to cultivation and orchard management. In addition to being unsatisfactory in bearing, neglected trees are very apt to become far more subject to attacks of fungous diseases and insect pests.

A common practice in the Southern States is that of renting the land between the rows to tenants, reserving a narrow strip on either side of the row to be cultivated and fertilized by the owner. As the trees approach the bearing age this strip is widened until all the land is included, after which cover crops only are grown between the rows. A good many soils in which pecan trees are now being planted are of such low fertility that they should be replenished with plant food rather than be further impoverished with intercrops. Of the crops being grown between the rows, cotton and corn are the most common, although truck crops are not infrequent. Legumes, such as cowpeas, velvet beans,[1] lespedeza, and bur clover, are most commonly used for soiling purposes.

BEARING AGE.

Owing to the infancy of the industry, very little data as to the ages at which pecan orchards come into bearing are yet obtainable. This lack of information is partly due to the fact already made clear that with few exceptions practically all orchards planted prior to 1903 were of seedling trees and therefore of very uncertain bearing habits and partly for the reason that a great majority of the grafted and budded trees were of varieties which later proved to be shy bearers. Of the trees which have been planted since 1903 a great many are bearing to some extent. It is not unusual for trees of some varieties when grown under favorable conditions to mature a few nuts by the end of the second or third season after transplanting from the nursery to the permanent orchard location. A few nuts, however, can not be considered a crop. It is not improbable that such early bearing is detrimental to the vitality of the trees. In the belief that trees should not be allowed to bear until they have attained size, root hold, and constitutional vigor proportionate to that of maturity, some of the leading orchardists are now managing their orchards so as to prevent commercial production of nuts until the trees are 8 to 10 years of age.

NUT HANDLING.

HARVESTING.

In the latitude of north Florida the period of ripening and harvesting begins with certain varieties in some years as early as September 5 and with others extends until late into December.

The hulls open partly or entirely and the nuts fall to the ground, or they are whipped from the trees with poles of bamboo or other light material, after which they are gathered up and taken to shelter. No machinery has yet been devised for separating the nuts from the hulls; consequently this work is done by hand. In sections where the pecan is native, professional thrashers beat the nuts from the trees for a stipulated fee or for a portion of the crop, according to agreement.

In order to dry the nuts thoroughly as soon as separated from the hulls they are spread to a depth of not more than 3 inches upon racks with perforated bottoms, so placed that the air will have free circulation above and below. With frequent stirrings the process of drying may be hastened so that in favorable weather the nuts may be ready for market in from 10 days to 2 weeks. A very appreciable loss in weight by evaporation will continue for some weeks following the ordinary period of drying.

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[1] The velvet bean is a remarkably vigorous grower and special precaution should be taken to prevent it from running over the young pecan trees, causing them to break down with the weight of the vines.

MARKETING.

Comparatively few nuts of the improved varieties reach the general markets. They are largely sold to nurserymen for use as samples, occasionally to seedsmen, and to tourists, fancy confectioners, private consumers, and recently to a rapidly increasing class of individuals engaged in promoting land sales of orchard property. The nuts are put up in any shape or style of package that may suggest itself, and shipments are sent by mail or express directly from the producer to the consumer. The pound is the unit of measure by which such sales are made. No standard package has been adopted by the trade and so far as known no grower has his own trade-mark, as is the case with leading growers of citrus and other fruits.

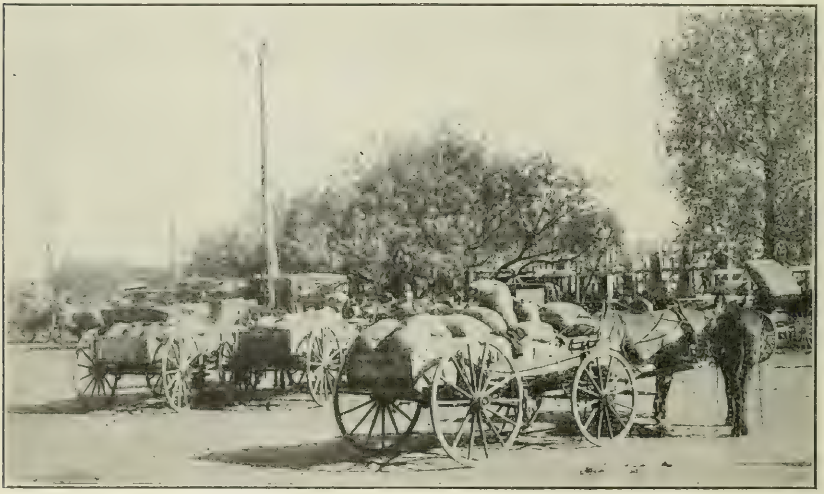

FIG. 24.—Wagons loaded with native pecans in Texas awaiting the arrival of buyers.

When thoroughly dried the wild nuts are placed in burlap sacks holding 100 to 150 pounds and hauled to the local markets, where they are inspected and bid upon from the wagons drawn up in the streets much the same as grain dealers buy wheat in the Northern States. Figure 24 shows three wagon loads of pecans in the central part of a Texas town[1] awaiting the arrival of buyers. From the local buyers they are sent in car lots to the larger markets, principally in San Antonio, New Orleans, Kansas City, St. Louis, Chicago, Cincinnati, Buffalo, and New York, whence they are distributed to smaller cities.

CLEANING, POLISHING, AND TINTING.

As the harvesting season extends over a period of two to three months, a large proportion of the nuts become considerably discolored and their surfaces more or less covered with particles of soil. To remedy this condition the nuts are rotated in cylinders of several hundred pounds capacity; the rubbing together in the cylinders removes the dirt and cleans and polishes the surfaces of the nuts, and they are then known as "polished" pecans. During the polishing process the natural rich appearance of the nuts is lost. Another common process by which wild pecans are prepared for market consists in the immersion of the nuts in a reddish dyeing solution, after which they are dried and polished by the method just described. The latter operation is known as "tinting" or "staining." Nuts thus treated may be readily detected by their bright, unnatural color, which is easily removable with a moistened finger.

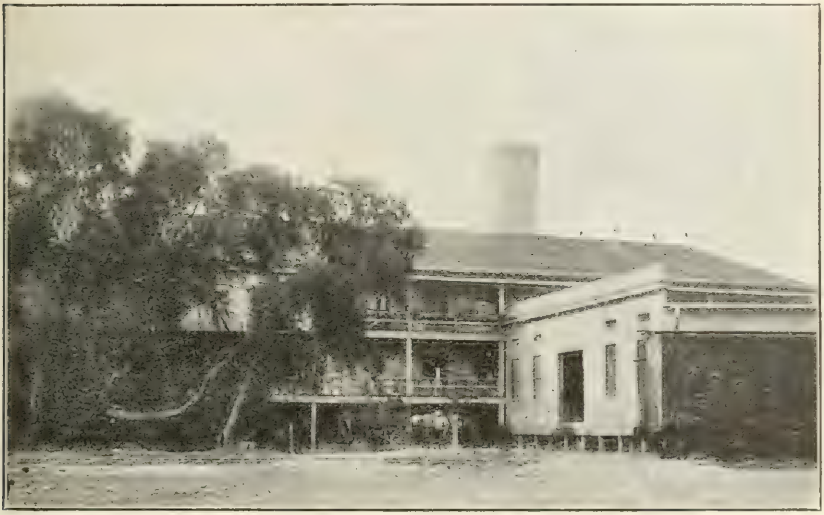

FIG. 25.—A pecan crackery.

CRACKING.

The invention of machinery for the cracking of pecans without breaking the kernels is undoubtedly more largely responsible for the marked increase in the demand for pecan products during recent years than any other single factor. Some crackeries in the cities of San Antonio, St. Louis, Chicago, and New York are supplied with machines having a daily capacity of 500 to 800 pounds each. Figure 25 shows a crackery[1] in San Antonio in which 30 to 40 of these machines are installed, having a total maximum capacity of 20,000 pounds daily. After the nuts are cracked the kernels are separated from the shells by hand, generally within the same crackery. Of the wild product, approximately 60 per cent of the total weight of the nut is shell, or about 40 per cent kernel. Of those cracked, depending largely upon the character of the nut itself, the perfection of the machine, and the skill of the operators, from 75 to 80 per cent by weight is separated from the shell in unbroken half kernels. These kernels are placed in boxes, barrels, or other packages and sent to the retail markets, where the present prevailing price ranges from 60 to 85 cents a pound.

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[1] San Saba, Tex. Photographed Nov. 12, 1910.

SIZING.

Public fancy is most readily attracted by mere bigness, and, as most of the cracking machines do not adapt themselves to varying sizes without special adjustment, the need of uniformity in size becomes apparent. To meet this exigency various sizing devices have been perfected. The type of device used by at least one of the large cracking companies consists of a hollow cylinder 24 feet long and 2 feet 3 inches in diameter, one end being slightly elevated. This cylinder is made up of three sections of equal length composed of iron rods placed equal distances apart, the distance varying in each section. The pecans are fed into the upper end of the cylinder, which has the smallest spaces between the rods. The cylinder is rotated slowly, the smallest nuts falling between the rods, while those of the larger sizes are carried forward. In experiments made by this Department with pecans of named varieties it has been found that a diameter difference of one-sixteenth of an inch is sufficient to constitute a difference between sizes.

VARIETIES.

ORIGIN OF VARIETIES.

Single trees possessing such superior merit over those of the general average in the matter of size, quality of nut, thinness of shell, productiveness, and other characteristics as to justify their propagation by grafting or budding have been given individual names and established as varieties. Varietal names apply to the original tree and to all trees grafted or budded from it, but not to those grown from its seed. Ordinarily these original trees are chance seedlings; exceedingly few varieties have thus far resulted from systematic breeding. Since attention has been called to the value of such individual trees, several hundred have been discovered, and more than 100 have been propagated as new varieties. Of these new varieties, however, comparatively few have proved to be of sufficient value to warrant their general sale to the public. The development of varieties superior in one or more respects to those already established and of varieties especially adapted to given localities is greatly to be commended, but unless a nut is plainly of special merit the attempt to add it to the present list of varieties should be discouraged, as mediocre sorts are already very numerous. It takes time to prove the value of a good variety in any locality; many good sorts are already available from which to select, making it not worth while to pay fancy prices for propagating wood or nursery-grown trees of any new sort, no matter how much may be said in its favor. In this bulletin the discussion of individual varieties is limited to such sorts as are best known or have been thought by some to be more or less promising.

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[1] Photographed Nov. 7, 1910.

SELECTION OF VARIETIES.

No factor in pecan culture is of greater importance than the selection of varieties for planting. Upon it alone may depend the success of the orchard. The following general suggestions are intended to be of service to the prospective planter.

(1) Ordinarily, varieties do not readily adapt themselves to soil and climatic conditions differing widely from those common to their place of origin.[1] Unless varieties have already demonstrated their adaptability to the soil and climatic conditions in a given locality they should be tested experimentally before being planted commercially.

(2) As far as practicable, varieties which have proved to be at least fairly resistant to fungous diseases and insect pests should be selected.[2]

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[1] Evidence of this statement lies in the fact that when taken to the more humid climate of the Eastern States a number of the leading varieties (including San Saba, Sovereign, Kincaid, and Halbert) which originated in the semiarid portions of Texas have developed a marked degree of susceptibility to the fungous disease known as pecan scab. Furthermore, experience thus far has not been such as to encourage the planting of eastern varieties in the semiarid portions of the Southwestern States or southern varieties in the North other than to an experimental extent. Northern varieties have not yet been tried in the South to any great extent.

[2] It is highly improbable that any variety will ever be discovered which will be altogether immune under all conditions to fungous diseases or insect pests; but some varieties are known to be less subject to certain diseases than others and considerable evidence at hand indicates that some are less affected by certain insect pests than others.

(3) The market for which the nuts are intended should be borne in mind at the time of selecting varieties for planting.[1]

PAPERSHELL PECANS.

With reference to the pecan the term "papershell" has been extended in its application until it is now practically without significance. Originally applied to those types of pecans having such thin shells that one nut could easily be cracked when two were placed in the hand and crushed together with both hands, the term during recent years has been made to include all cultivated varieties, many of which have fully as hard shells as the average wild nuts. Properly speaking, the term "papershell" never referred to a particular variety; its correct application has been only with reference to the group of varieties having very thin shells.

DESCRIPTION OF VARIETIES.

No attempt is made in this publication to discuss the merits of all varieties known to the trade; only such as are well known or at some time have been thought to give promise as future varieties are included.

Alley.

From Jackson County, Miss. Widely disseminated since being introduced in 1896; size medium; shell thin; kernel plump; flavor good; a medium to heavy bearer and symmetrical, vigorous grower, somewhat subject to scab under certain conditions. Should be planted conservatively.

Appomattox.

Recently introduced from Dinwiddie County, Va. Parent tree not in normal condition, owing to stable built under tree. Size medium; shell of average thickness; flavor said to be good; believed to be promising for northern planting.

Atlanta.

From southwestern Georgia. Very much subject to scab.

Aurora.

From Mobile County, Ala. Not yet propagated to a great extent; size large; shell somewhat thick; partitions rather corky; kernel fairly plump; flavor good to very good. Probably adapted to markets catering to large nuts.

Beman.

From Hancock County, Ga. Propagated to a limited extent only. Size below medium; shell rather hard; kernel plump, bright colored, rich, and of excellent flavor. Very productive. Promising for north Georgia and vicinity.

Beveridge.

From Orange County, Fla. Large, but too shy in bearing and too much subject to scab to be of value.

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[1] For the market in which pecans are sold without being cracked, nuts of large size have a distinct advantage at the present time; in all probability this preference for size will continue. The varieties of medium size have certain cultural advantages over the larger types in that they are less often shy or irregular in bearing and are generally better fillers.

Bolton.

From Jefferson County, Fla. Size above medium; shell moderately thin; kernel not always plump; flavor fairly good. Bearing record not proved. Needs further testing.

Bradley.

From Baker County, Fla. Size below medium; shell of average thickness, hard; kernel plump; flavor very good. Very productive. Especially promising for Florida and south Georgia.

Burkett.

From Callahan County, Tex. Size large; shell thin; kernel plump; flavor excellent. Said to be productive. Should be especially adapted to planting in west Texas.

Centennial.

From St. James Parish, La. The first variety known to be propagated. Widely disseminated but very tardy in bearing. No longer planted to any considerable extent.

Claremont.

From Concordia Parish, La. Not yet extensively propagated. Size medium; shell somewhat thick; kernel plump; quality rich; flavor excellent; very productive. Considered very promising, especially for planting in northern range of the area adapted to southern varieties.

Colorado.

From San Saba County, Tex. Little propagated as yet. Size large; shell somewhat thick; kernel plump; quality rich; flavor excellent. A seedling of San Saba. Probably especially adapted to planting in western Texas.

Curtis.

From Alachua County, Fla. Size below medium; shell thin; kernel plump; quality rich; flavor excellent. Very productive. Widely desseminated. Popular in Florida.

Daisy.

From Comal County, Tex. Widely desseminated though not extensively planted. Size medium; shell moderately thin; kernel plump; quality rich; flavor very good. Tree vigorous; said to be productive; probably best adapted to western Texas.

Delmas.

From Jackson County, Miss. Widely disseminated. Size large to very large; shell moderately thin; kernel plump; quality good to very good; flavor excellent. Tree vigorous; productive. Very much subject to scab under certain conditions.

Dewey.

From Jefferson County, Fla. Size medium; shell thin; kernel plump; quality rich; flavor excellent. Tree of rather awkward habit and thus far irregular in bearing.

Frotscher.

From Iberia Parish, La. Widely disseminated. Size large; shell very thin; kernel moderately plump, often dark colored; quality fair; flavor medium. Popular in southwestern Georgia and parts of Louisiana.

Georgia.

From Mitchell County, Ga. Size above medium; shell thick, rather hard; kernel plump; quality good; flavor pleasant. Very prolific but extremely subject to scab in most places where tried. Should be avoided for the present.

Greenriver.

From Henderson County, Ky. Propagation recently begun. Size somewhat below medium; shell of average thickness; kernel plump; quality rich; flavor excellent. A promising variety, especially for northern planting.

Hadley.

From McDuffie County, Ga. Propagated to some extent in Grady County. One of the very large varieties, not yet well known.

Halbert.

From Coleman County, Tex. Widely disseminated, mainly by scions used in top-working. Size small; shell very thin; kernel unusually plump; quality rich: flavor excellent. Very prolific. Especially adapted to planting in western Texas and places of similar climatic conditions.

Hall.

From Jackson County, Miss. Not widely disseminated. Size very large; shell thin: kernel usually plump, frequently defective; quality dry; flavor medium. Very prolific.

Havens.

From Jackson County, Miss. Not widely desseminated. Size medium to large; shell very thin; kernel plump; quality good; flavor sweet though sometimes slightly astringent. One of the most promising new varieties, especially for Gulf coast planting.

Hodge.

From Clark County, Ill. Not propagated to any great extent. Size medium; shell rather thick; kernel somewhat shriveled; quality fair; flavor pleasant.

Hollis.

From San Saba County, Tex. Not widely disseminated outside of central and western Texas. Trees of this variety were at one time sold to some extent under the name *Post's Select*. Size medium to large; shell thick, soft; kernel plump; quality good to very good; flavor sweet.

Indiana.

From Knox County, Ind. Not yet widely disseminated. Considered highly promising for planting in the northern range. Size medium; shell of average thickness; quality said to be good.

Jacocks.

From Orange County, Fla. Size large and shell thin; awkward grower; irregular bearer and much subject to pecan scab.

James.

From Madison Parish, La. Not widely disseminated. Size medium; shell thin; quality rich; flavor sweet. Very prolific. Thought to be highly promising for the northern portion of the range of southern varieties.

Jewett.

From Jackson County, Miss. One of the earliest varieties disseminated. Fairly prolific but a very poor filler. Tree trunks of this variety are often subject to a peculiar bark disease. No longer planted by those familiar with it.

Just.

From Tarrant County, Tex. Recently introduced. Size small; shell very thin; kernel slightly shrunken; quality rich; flavor sweet. Said to be very prolific. Evidently well worthy of trial in central and western Texas.

Kennedy.

From Alachua County, Fla. Not widely disseminated. Size medium to large; shell moderately thin; quality very good; flavor sweet. Very productive in some years. Inclined to be irregular. Thought to be especially adapted to central and northern Florida.

Kincaid.

From San Saba County, Tex. Well disseminated in central and western Texas. Size large; shell of medium thickness; kernel plump; quality very good; flavor sweet. Very prolific. Especially recommended for central and western Texas. Very much subject to scab in the Atlantic States.

Lewis.

From Jackson County, Miss. Recently introduced. Size large; shell of medium thickness; kernel plump; quality rich; flavor pleasing. Said to be productive. Believed by introducer to be very promising, especially for Gulf coast planting.

Magnum.

From Mitchell County, Ga. Very much subject to scab. Little planted at present time.

Major.

From Henderson County, Ky. Recently introduced. Not yet widely disseminated. Size slightly below medium; shell thin; kernel unusually plump; quality rich; flavor excellent. Considered especially promising for planting in northern range.

Mantura.

From Surry County, Va. Size medium to large; shell thin; kernel not always plump at tip, somewhat shrunken; quality good; flavor good. Said to be productive. Believed to be especially promising for planting in the northern range.

Melançon.

From St. James Parish, La. Size medium to large; shell somewhat thick; kernel fairly plump; quality medium. This variety has been considerably confused since its introduction. At one time trees of Melançon and Van Deman were sold under the common name of *Paragon*, and it is highly probable that the variety disseminated from Ocean Springs, Miss., as *Capital* is true Melançon. The nuts of *Capital* appear to be identical with those of Melançon, and the scions with which *Capital* was first propagated were obtained from a grafted tree of about the same age as other grafted trees which are known to have been propagated with scions obtained from the same parish.

Mobile.

From Mobile County, Ala. Well disseminated, especially in southwestern Georgia. Size medium to large; shell moderately thin; kernel usually plump, frequently very defective; quality fair; flavor fair. Very productive, but thus far generally objectionable after second or third crop because of great percentage of defective kernels.

Moneymaker.

From Madison Parish, La. Widely disseminated. Size medium; kernel fairly plump; quality fair; flavor sweet. Very prolific. Especially suited to planting in northern range of the area adapted to southern varieties.

Moore. SYNONYMS: *Long Moore, Moore No. 1, Moore No. 2.*

From Jefferson County, Fla. Size below medium; shell of average thickness; quality fair; flavor fair. Unusually productive and one of the earliest to mature. Well suited to northern Florida.

Nelson.

From Hancock County, Miss. Size very large; shell thick; kernel generally plump, though often very defective; quality medium; flavor good. Tree unusually vigorous; very productive.

Owens.

From Coahoma County, Miss. Just being introduced. Size large; shell thin; kernel fairly plump; quality medium; flavor good. Parent tree said to be very productive. Evidently promising for planting in the northern range of the area adapted to southern varieties.

Pabst.

From Jackson County, Miss. Widely disseminated. Size large; shell somewhat thick; kernel usually plump; quality good; flavor sweet. Generally, productive, though by some thought not to be an early bearer.

Post. SYNONYM: *Post's Select.*

From San Saba County, Tex. Not widely disseminated. Size medium; shell thick; kernel somewhat shrunken; quality good; flavor delicate. Much confused with Hollis.

President.

From Duval County, Fla. Well disseminated in northern Florida. Size medium; shell of medium thickness; kernel plump; quality good; flavor pleasant. Vigorous and productive. Considered as especially promising for central and northern Florida.

Randall.

From Alachua County, Fla. Not widely disseminated. Size large; shell rather thick; kernel plump; quality rich; flavor sweet. Prolific, though irregular in bearing. Evidently well suited to central and northern Florida.

Reuss.

From Ascension Parish, La. Not yet disseminated. Size slightly below medium; shell thin; kernel plump; quality good to very good. Evidently promising, especially for northern range of area adapted to southern varieties.

Robinson.

From Orange County, Fla. Not widely disseminated. Size large; shell rather thick; kernel fairly plump; quality good; flavor pleasant. Very productive. Evidently promising for planting in the southern limits of the area adapted to pecans.

Robson.

From Jackson County, Miss. More or less widely disseminated, though not well known. Size medium; shell thin; kernel somewhat shrunken; quality good; flavor pleasant. From same parentage as Russell, resembling that variety in many respects.

Rome. SYNONYMS: *Columbian, Twentieth Century, Pride of the Coast*, etc.

From St. James Parish, La. Widely disseminated and very well known. Size large to very large; shell thick; kernel usually somewhat shrunken, often very defective; quality medium; flavor fair. Very irregular in bearing habits. No longer recommended for planting.

Russell.

From Jackson County, Miss. Widely disseminated. Size medium; shell very thin; kernel somewhat shrunken; quality good; flavor sweet. Prolific; said to be sensitive to cold weather.

San Saba.

From San Saba County, Tex. Very well known. Size small; shell unusually thin; kernel very plump; quality very rich; flavor excellent. Highly productive. Especially adapted to central and western Texas. Not suited to eastern planting.

Schley.

From Jackson County, Miss. One of the best known and most widely disseminated varieties. Size medium to large, although often variable, even on same tree; shell very thin; kernel plump; quality very rich; flavor excellent. Moderately productive, but a regular, annual bearer. Although sometimes quite subject to scab, it is one of the most popular varieties at the present time.

Seminole.

From Jefferson County, Fla. Not well known. Size medium; shell thin; kernel plump; quality rich; flavor sweet.

Senator.

From Mitchell County, Ga. Not well known. Small; hard shelled; prolific. No longer thought to be promising.

Sovereign. SYNONYM: *Texas Prolific.*

From San Saba County, Tex. Very well known. Size large; shell of medium thickness; kernel plump; quality rich; flavor sweet. Unusually prolific. Especially well adapted to planting in central and western Texas. Not adapted to the Eastern States.

Stuart.

From Jackson County, Miss. More extensively planted than any other variety. Size medium to large; shell of average thickness; kernel plump, usually breaks into crumbs while being extracted; quality good; flavor sweet. Moderately productive. Has succeeded in nearly all parts of the range adapted to southern varieties east of central Texas.

Success.

From Jackson County, Miss. Of comparatively recent introduction. Size large to very large; shell moderately thin; kernel usually very plump; quality rich; flavor very good. Generally reported to be highly prolific. Very promising.

Superb.

From Jackson County, Miss. Not yet disseminated to any great extent. Size medium to large; kernel fairly plump, often defective; quality fair. Judging from specimens examined, this is not a promising variety.

Taylor.

From Harrison County, Miss. Known for some time, but not widely disseminated. Size medium to large; kernel plump; quality very good; flavor sweet. Evidently well adapted to Gulf-coast planting.

Teche.

Thought to be from Iberia Parish, La. Introduced by confusion with Frotscher. Size medium to small; shell of average thickness; kernel fairly plump; quality medium to poor; lacking in flavor. Unusually productive and generally hardy over the entire range of southern varieties from Louisiana eastward.

Van Deman.

From St. James Parish, La. One of the most widely disseminated of all varieties. Size large to very large; shell of medium thickness; kernel plump; quality rich; flavor sweet. Very popular until recently, when it developed a susceptibility to scab serious in some sections. In the young orchards of the Eastern States this variety has not yet proved to be prolific.

Warrick.

From Warrick County, Ind. Not yet generally disseminated. Size slightly below medium; shell moderately thin; kernel plump; quality rich; flavor excellent. Parent tree reported to be prolific. Evidently a very promising variety for planting in the northern range.

Waukeenah. SYNONYMS: *Round Moore, Moore No. 1, Moore No. 2.*

From Jefferson County, Fla. Quite generally disseminated in northern Florida. Size small; shell of average thickness; kernel generally shrunken; quality below medium; flavor poor. Very prolific. One of the earliest to mature. Especially adapted to central and northern Florida.

Wolford.

From Collin County, Tex. Not widely disseminated. Size medium or slightly below; shell very thin; kernel plump; quality rich; flavor very good. Evidently well worthy of planting in central and western Texas.

Young.

From St. Martin Parish, La. Widely disseminated, but not extensively planted. Size large; shell very thin; kernel somewhat shrunken; quality good; flavor sweet. Possibly parent to Russell, which it resembles closely.

Zink. SYNONYM: *Big Z.*

From Jackson County, Miss. Recently introduced. Much like Frotscher in nut characteristics. Size large; kernel often shrunken; quality good. Though of attractive appearance, because of its deficiency in plumpness of kernel it should be held as a test variety.

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[Synonyms are distinguished from the correct varietal names by the use of italic type.]

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BUREAU OF PLANT INDUSTRY—BULLETIN NO. 252.

B. T. GALLOWAY, *Chief of Bureau.*

STUDIES OF FUNGOUS PARASITES BELONGING TO THE GENUS GLOMERELLA.

BY

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AND

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Fruit-Disease Investigations.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., April 15, 1912.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 252 of the series of this Bureau the accompanying manuscript entitled "Studies of Fungous Parasites Belonging to the Genus Glomerella," by Dr. C. L. Shear, Pathologist in Charge of Grape and Small-Fruit Diseases, and Mrs. Anna K. Wood, formerly Scientific Assistant in the Office of Fruit-Disease Investigations. This paper has been submitted by Mr. M. B. Waite, Pathologist in Charge of the Office of Fruit-Disease Investigations.

This bulletin gives the results of studies of a group of fungous parasites of great economic importance. Few fruits are free from the attacks of this fungus. The life histories and relationships as well as the physiological and pathological characteristics of the organism from 36 different host plants are herein recorded, in many cases for the first time. It has been found that what had heretofore been regarded as distinct species of fungi restricted to certain host plants are in reality merely races or strains of one species which is capable of infecting various hosts.

These facts have a very direct and important bearing upon the practical problems of the prevention and control of the widespread and serious diseases caused by these parasites and also upon the broader general biological questions connected with the evolution of plant parasites.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B.P.I.—746.

STUDIES OF FUNGOUS PARASITES BELONGING TO THE GENUS GLOMERELLA.

INTRODUCTION.

The name Glomerella was first applied by Von Schrenk and Spaulding (70)[1] to the ascogenous form of the fungus producing the bitter-rot of the apple and the ripe-rot of the grape, usually referred to in its conidial condition as Gloeosporium or Colletotrichum. The same fungus, or fungi belonging to the same genus, attacks a great variety of other plants and produces diseases which are sometimes called "anthracnose," of which the anthracnose of the bean is a familiar example. In current usage, the term "anthracnose" is applied to diseases caused by fungi belonging to a few other genera besides Glomerella. It would be better if the name "anthracnose" were restricted to the disease caused by Glomerella. It still remains to be determined, however, whether some of the so-called anthracnoses are caused by Glomerella or not, as the complete life histories of the organisms are not all definitely known at present.

This genus of fungi is of vast economic as well as scientific importance. Few fruits are free from its attacks, and it is known to occur on a great variety of other hosts, from the palms to the highest flowering plants. It is also cosmopolitan in its distribution, though most abundant in temperate and tropical regions.

All the facts connected with the life history of a parasite, the causes of its variability, its behavior under different conditions, and its relation to different hosts are essential to the most comprehensive and successful development of practical methods for the prevention and control of disease.

The primary objects of this investigation have been to determine the life histories and habits and the identity or relationship of the forms of Gloeosporium and Colletotrichum found upon the same hosts and on different hosts. Attention has also been given to the physiological features of the fungi and the possibility of their passage from one host to others. Careful studies of pure lines or races originating from single ascospores and single conidia have been carried on through many generations in order to determine, if possible, the conditions affecting the production of the ascogenous stage and the causes of the variations which sometimes appear in pure cultures.

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[1] The numbers appearing in parentheses in this bulletin refer to the list of literature cited on pp. 101-105.

The first production of perithecia of Glomerella in pure cultures, so far as records have been found, was by Atkinson, as reported by Stoneman (89) in 1898. This ascogenous form was named *Gnomoniopsis cingulata* Stonem. (89). The conidial form had been described by Atkinson (2) as *Gloeosporium cingulatum*. Since Miss Stoneman's work was done considerable study has been given by different investigators to the life histories and relationships of Gloeosporium and Colletotrichum occurring upon different hosts. The systematic study and segregation of the species in this group of organisms has usually been based upon the supposed fixity of their host relationships and on some slight but inconstant differences in their morphological characters. A form occurring on a certain host was generally assumed to be distinct from one occurring upon another host, especially if there happened to be some slight difference in the measurements of the few spores observed or in the appearance of the affected portion of the host. Later, slight differences in the last two particulars led to the segregation in some cases of several species from the same host plant. Species were also sometimes based primarily upon the occurrence of the fungus upon different parts of the host. If the fungus at hand happened to occur upon the fruit it might be regarded as distinct from a form which was found upon the foliage or upon a shoot or branch of the same host. It is therefore necessary, before any satisfactory understanding or designation of these organisms can be obtained, to determine not only the ordinary range of variability of their morphological characters and their complete life histories, but also their host relationships. Where no fairly constant morphological characters can be found to separate the forms growing upon different portions of the same host plant, they should without question be referred to the same species. Where they occur upon different hosts, but still show no reasonably constant characters for identification and separation, they should still be regarded as one species. If it be held that these latter should be separated as so-called physiological species, the burden of proof falls upon those who take that position. Such a position can only be sustained by a sufficient number of successful cross-inoculation experiments to demonstrate that the organism will not pass from one host to another.

The present paper covers the investigation of members of this group of organisms obtained from 45 different host plants.

PREVIOUS INVESTIGATIONS.

Previous work with these organisms may be divided into two parts: That primarily of a systematic or taxonomic character and that chiefly concerned with cultural, cross-inoculation, and life-history studies.

The conidial form of this genus of fungi is apparently much more common, conspicuous, and likely to be observed than the perithecial form. For this reason the majority of the species are much better known in their conidial condition than in any other and have been described principally under the names Gloeosporium and Colletotrichum, though some have apparently been referred to Cylindrosporium, Marsonia, and other similar genera. Four hundred and seventy-three species of Gloeosporium and Colletotrichum are given by Saccardo. This does not, as already suggested, include all of the species or forms that belong to this group, as some are found under other generic names. On the other hand not all the forms or species described under Gloeosporium and Colletotrichum are conidial stages of Glomerella.

It is quite certain, from a study of specimens and a comparison of the descriptions, that about 50 per cent of these so-called species can not be separated except on the basis of host relations or part of the host attacked. No monographic treatment of Gloeosporium and Colletotrichum has yet been attempted. The compilation of descriptions undertaken by Ellis and Everhart (33), in the Journal of Mycology, and that of Saccardo (67), in Sylloge Fungorum, are practically all we have.

Cross-inoculation experiments have been carried on at different times by different investigators. Owing to the various methods practiced in different cases and in some instances the lack of record of sufficiently definite information as to the details of the work, it is difficult satisfactorily to compare and coordinate the results. Southworth (84), Halsted (39, 40, 41), Cobb (20, 21), Clinton (19), Burrill (15), Edgerton (28, 29, 30, 31), Sheldon (77, 79), Chester (18), and Taubenhaus (90, 91) have made the principal contributions to this phase of the subject. A discussion of these results accompanied by tables will be found on subsequent pages.

Considerable attention has already been given by different investigators to cultural and life-history studies of these organisms. Among these may be mentioned the work of Southworth (84, 85), Atkinson (2), Stoneman (89), Clinton (19), Edgerton (28, 29, 30, 31, 32), Lasnier (55), von Schrenk and Spaulding (70), Sheldon (77, 78, 79, 80, 81), Shear (74), Barre (7, 8), Shear and Wood (75, 76), Koorders (54), and Scott (73). The work of Klebahn (51, 52) on Gloeosporium relates to species which are not congeneric with Glomerella.

PRESENT INVESTIGATION.

The present investigation was commenced by the senior writer in 1904. A brief summary of the early part of the work was published by the present writers (75) in 1907. At that time the life histories of the forms of Glomerella found on eight different hosts were briefly reported. During the same year a detailed description of the life history and behavior in cultures of *Glomerella rufomaculans vaccinii*. Shear (74) was given by the senior writer in connection with a general discussion of cranberry diseases. In 1908 the present writers (76) presented a summary of their work before the Botanical Society of America, a brief abstract of which appeared in 1909. At that time the life histories of forms obtained from 18 different hosts had been worked out. Since then the number has been doubled, and both the conidial and ascogenous stages of Glomerella from 36 different hosts have been studied and the conidial forms from 45 different hosts have been grown, as follows:

Glomerella cingulata (Stonem.) S. and v. S.

Conidia and perithecia produced either in culture or on the host:

Brya ebenus (L.) DC. (Jamaica ebony).
Caryota rumphiana Mart. (palm).
Cinnamomum zeylanicum Nees (cinnamon).
Citrus aurantium sinensis L. (sweet orange).
Citrus decumana (L.) Murr. (pomelo).
Citrus limonum Risso (lemon).
Citrus nobilis Lour. (mandarin).
Coffea arabica L. (coffee).
Costus speciosus (Koenig) Smith (spiral flag).
Curculigo sp.
Eriobotrya japonica (Thunb.) Lindl. (loquat).
Ficus carica L. (fig).
Ficus elastica Roxb. (rubber plant).
Ficus longifolia Schott.
Ginkgo biloba L.
Gleditsia triacanthos L. (honey locust).
Hedyscepe sp.=Kentia (palm).
Ligustrum vulgare L. (privet).
Malus sylvestris Mill. (apple).
Mangifera sp. (mango).
Maranta arundinacea L.? (arrowroot).
Oxycoccus macrocarpus (Ait.) Pers. (cranberry).
Persea gratissima Gaertn. f. (avocado).
Phormium tenax Forst.
Pimenta acris (Swartz) Kostel.
Piper macrophyllum Swartz (pepperwort).
Pitcairnia corallina Linden.
Psidium guajava L. (guava).
Ribes oxyacanthoides L. (gooseberry).
Rubus occidentalis L. (black raspberry).
Thea japonica (L.) Baill. (camellia).
Thea sinensis L. (tea).
Theobroma cacao L. (chocolate nut).
Vitis labrusca L. (Concord grape).

Conidia only produced:

Annona cherimola Miller (cherimoya).
Crataegus sp. (hawthorn).
Rubus trivialis (cult.) (white dewberry).
Smilax medica Schl. and Cham.
Vanilla planifolia Andrews (vanilla).

Glomerella gossypii Edge.

Both conidia and perithecia produced in cultures:

Gossypium hirsutum L. (cotton).

Glomerella lindemuthianum Shear.

Both conidia and perithecia produced in cultures:

Phaseolus vulgaris L. (wax bean).

GLOEOSPORIUM LAGENARIUM (PASS.) SACC. AND ROUM.

Conidia only produced:

Citrullus vulgaris Schrad. (watermelon).
Cucumis sativus L. (cucumber).
Cucurbita pepo L. (squash).

GLOEOSPORIUM MUSARUM CKE. AND MASS.

Conidia only produced:

Musa paradisiaca sapientum (L.) Kuntz (banana).

METHODS OF STUDY.

DEVELOPMENT IN MOIST CHAMBER.

Apparently normal and healthy leaves, twigs, and fruits taken from plants showing a slight infection or suspected of being infected with anthracnose in a dormant or hibernating condition were found in most cases to develop typical spots of rot with acervuli and frequently perithecia when kept in a moist chamber. Such material was first immersed from 5 to 15 minutes in a 1 to 500 or 1 to 1,000 solution of corrosive sublimate to destroy any spores of the fungus which might be present. That this treatment is sufficient to destroy all the known reproductive bodies of Glomerella has been demonstrated by treating conidia, appressoria, and ascospores with these solutions for different periods. Treatment with a 1 to 1,000 solution of corrosive sublimate for three minutes has been found to kill all the spore forms.

After the foregoing treatment the specimens were rinsed in sterile water and placed in sterile glass moist chambers.

CULTURES.

Cultures have usually been started from conidia or ascospores obtained from fresh material from the field or greenhouse or from spores developed on parts of the host kept in a sterile moist chamber in the laboratory. To obtain pure cultures of the organism and to isolate single spores, poured plates of corn-meal agar have been generally used. Various solid or liquid media have been tried, but none has proved more satisfactory than corn-meal agar, which is prepared as follows: To four teaspoonfuls of corn meal add 1 liter of distilled water. Keep in water bath for one hour at a temperature below 60° C. Strain through gauze and to the filtrate add 1 per cent of agar flour. Steam three-quarters of an hour. Filter through filter paper. Tube and autoclave for 15 minutes at 115° C.

In isolating single spores to obtain pure-line cultures, special Petri dishes with very thin bottoms are used. After the plates have been poured and the agar cooled, the dishes are placed upside down on the microscope stage and single spores located with an objective of sufficient power to distinguish and identify them clearly through the bottom of the dish. The location of the single spores is then indicated by a small circle of red ink on the bottom of the Petri dish. The culture medium in the dish should be very shallow, so that the range of the objective will reach through the full depth of the medium and permit the detection of spores lying at different levels. Some practice in getting the proper dilution of the spores in the medium is required. When the spores are too numerous in the plates it is frequently difficult to find one sufficiently isolated to be readily removed without the possibility of others being transferred with it. When the spores are too few, however, much time is required in searching over the plate to locate them.

Spores have also been isolated by the method described by Kauffmann (50). This method consists in sprinkling sterile water containing the spores on the surface of the agar after it has been poured in a Petri dish and cooled. When the medium has solidified, the spores are located with the microscope by examining the surface of the agar with the cover of the dish removed. This method has the advantage of insuring the distribution of the spores in practically one plane—i. e., on the surface of the medium—and permitting the use of a higher power objective than could be used when searching through the bottom of the dish. It has the disadvantage, however, of necessitating the removal of the cover during the search for the spores and thus greatly increasing the liability of contaminating the culture; but this tendency can be largely overcome by making the examination in a thoroughly protected culture room. With thin dishes and a thin layer of culture medium, spores not less than eight microns long can be located very satisfactorily by the first method. With smaller spores requiring high power for identification, the second method is preferable. As soon as the spores have germinated, which usually requires 8 to 16 hours, they are carefully transferred by means of flattened sterile needles to tubes of the same medium. If the germinating spore is transplanted near the upper margin of the agar and close to the wall of the tube, it may be usually located with the microscope and its actual transfer to the tube verified.

Pure lines, races, or strains can be isolated in this manner, then propagated indefinitely by transfer to subcultures or by the poured-plate method, thus making it possible to study the behavior of the organism in relation to various factors of nutriment and environment through as many generations as is desired.

STUDIES OF GLOMERELLA FROM DIFFERENT HOSTS.

The following records give the results of the writers' studies of Glomerella, Gloeosporium, and Colletotrichum from various host plants, describing their behavior on leaves, stems, and fruits in moist chamber and also in pure cultures. This matter is arranged alphabetically with reference to the host plants. Following the name of the host in each case is the name which has been adopted for the organism, with synonyms also where they have been satisfactorily determined.

ANNONA CHERIMOLA MILL. (CHERIMOYA).

Gloeosporium rufomaculans (Berk.) Thüm.

Poured plates of conidia from an acervulus on a stem of cherimoya received from Miami, Fla., were made on April 9. Growth was rapid. The mycelium was white at first, changing later to dark greenish or smoke color and forming circular spots. Subcultures on corn-meal agar in tubes produced an abundant growth of mycelium and acervuli with a few setæ. Later many setæ appeared in these cultures. Though the cultures were kept growing until January 19 of the following year, no perithecia were ever found. The fungus from this host does not appear to have received a specific name. The characters of the acervuli and the shape and measurements of the spores averaged about the same as those from the apple, grape, and citrus fruits.

BRYA EBENUS (L.) DC. (JAMAICA EBONY).

Glomerella cingulata (Stonem.) S. and v. S.

Several leaves of the host plant, collected in the greenhouse on January 19, were placed in sterile moist chamber. On February 8 acervuli of Gloeosporium were present on several of the leaves. On February 17 many mature perithecia were found associated with the acervuli. An ascus and ascospores are shown in Plate II, figures 23 and 23 *a*. The fungus showed no characters by which it could be distinguished from the Glomerella on apple and grape. No fungus of this kind appears to have been heretofore reported upon this host.

Plates were poured February 8, using conidia from a leaf taken from an apparently healthy plant in the Department greenhouse. The acervuli from which these cultures were made developed upon this leaf in a sterile moist chamber. Spores germinated quickly and subcultures in tubes of corn-meal agar were made by transferring single conidia. Growth in the plates was similar to that usually produced by Gloeosporium from apple or grape. Conidia were produced in both plates and tubes, but no very distinct acervuli were found. On February 17 the cultures were found to be contaminated with a mold and had to be discarded. Perithecia were not found in them. The cultures were perhaps not old enough at the time for perithecia to have had an opportunity to develop.

CARYOTA RUMPHIANA MART. (PALM).

Glomerella cingulata (Stonem.) S. and v. S.

On January 29 leaves from a plant of this species, which was growing in the greenhouse and which had produced leaves with spots showing conidia of Glomerella, were placed in a sterile moist chamber. On February 3 a number of the leaves showed acervuli with conidia ranging from 13.5 to 25 by 4.5 to 6 μ. Setæ were present but not abundant. The conidiophores appeared to average a little shorter than is usual with forms from other hosts, being 9 to 15 μ in length. On February 18 many mature perithecia agreeing in practically all respects with *Glomerella cingulata* were found on these leaves. Asci and ascospores are shown in Plate II, figures 28 and 28 *a*.

The conidial form has apparently been described as *Gloeosporium nanoti* Prill. and Delacr. (64).

On February 7 cultures in corn-meal agar tubes were made by transfer of spores from acervuli on the leaves in moist chamber just described. Typical conidia and acervuli were formed in a few days. These cultures were kept until July 7, but no perithecia were ever found.

CINNAMOMUM ZEYLANICUM NEES. (CINNAMON).

Glomerella cingulata (Stonem.) S. and v. S.

Leaves appearing perfectly healthy, taken from a greenhouse plant of this species, were placed in moist chamber. The leaves soon became discolored and several acervuli with conidia appeared. The conidial form agrees with *Gloeosporium ochraceum* Patterson (62).

On February 11 transfers of conidia were made from these acervuli to corn-meal agar tubes. These produced large acervuli and appressoria. Though kept until July 7 no perithecia were ever found. On April 30 more plates were poured from conidia from a leaf kept in moist chamber. A few peritheciumlike bodies were found in the plates on May 15. On May 23 some of these plates showed perithecia with mature asci. Subcultures to corn meal in flasks were made from the original tubes. These produced very few conidia but many sterile peritheciumlike bodies. Chlamydospores were also present. No asci were found in these cultures.

CITRULLUS VULGARIS SCHRAD. (WATERMELON).

Gloeosporium lagenarium (Pass.) Sacc. and Roum.

On November 17, plates were poured, using conidia from an anthracnose spot on a watermelon grown at Vienna, Va. Transfers from plates to corn-meal agar tubes were made. Numerous acervuli soon appeared in these plates and very dark setæ were present in abundance. The setæ, however, were dark only at the apex and light colored at the base, which is not the case with the setæ in most other forms. They also appeared to be somewhat shorter than usual. No perithecia or peritheciumlike bodies appeared in the cultures.

The fungus agrees with *Gloeosporium lagenarium* (Pass.) Sacc. and Roum. It seems probable that the fungus occurring on cucurbits is specifically distinct from the other species investigated, though Halsted (40) reports the successful transfer of the organism from bean and pear to citron, *Citrullus vulgaris* var. He also reports the successful transfer of the organism from watermelon to bean, and as a result reduces *Colletotrichum lindemuthianum* to synonomy, using *Colletotrichum lagenarium* (Pass.) E. and H., which is the older name, for anthracnose of bean as well as that of cucurbits. Evans (36) states that the fungus passes from bean to watermelon and vice versa, but the statement is apparently based upon Halsted's work (39) and not on his own experiments. Further cultures and the opportunity to study the perithecial form from watermelon may be necessary to determine this point satisfactorily. The experiments of Edgerton (30) and the present writers in attempting to transfer the organism from bean to cucurbits, as reported later, were all failures. The writers' inoculations with the form from grape and guava to watermelon, however, were entirely successful, but not conclusive as to the identity of *Colletotrichum lagenarium* and *Glomerella cingulata*, since the perithecial stage of the former is unknown.

CITRUS AURANTIUM SINENSIS L. (SWEET ORANGE).

Glomerella cingulata (Stonem.) S. and v. S.
Colletotrichum gloeosporioides Penz.

DEVELOPMENT ON LEAVES AND BRANCHES IN MOIST CHAMBER.

Since the fungus appeared to be present in a dormant or hibernating condition in the tissues of the leaves, as indicated by its appearance on apparently healthy leaves when their surfaces were thoroughly sterilized and placed in sterile moist chamber, several attempts were made to secure data which might throw some light upon the location of the fungus in the tissues and its original point of entrance. On March 6 apparently healthy leaves of various ages were taken from a blossoming tree in the greenhouse. These were treated as usual and placed in sterile moist chambers. On March 14 numerous acervuli were present on all the leaves except the youngest, which showed a number of discolored spots but no other external evidence of fungous infection. The acervuli on the older leaves usually appeared first at the base of the midrib, being preceded by a dark, water-soaked appearance of the tissue. In some cases the diseased area gradually spread toward the tip until the entire leaf was affected, as illustrated in Plate VI. At other times acervuli broke out almost simultaneously on the entire surface and were equally numerous both on the upper and under sides of the leaf. On March 25 all but the present year's leaves, which were not entirely discolored, were covered with the fungus. Small patches of mature perithecia were also present. Though kept until April 13, the young leaves showed no trace of acervuli or perithecia of Glomerella.

On April 30 two more apparently healthy leaves were taken from near the tip of a shoot bearing fruit one-half inch in diameter. These were sterilized and placed in moist chamber, and two leaves from the previous season's growth on the same branch were treated in the same way. On May 7, acervuli were abundant on the older leaves. On one, development was chiefly along the midrib; on the other, chiefly along the margins. The younger leaves showed no acervuli. On May 11 one of the younger leaves showed discoloration and a few acervuli at the base of the midrib. The other young leaf showed discoloration at the base, but had developed no acervuli on May 13 when the leaves were discarded.

On May 11 a young sterile shoot—that is, a shoot without a fruiting bud—was taken from a greenhouse plant and the surface thoroughly sterilized as usual. It was then cut into six segments, each one bearing a single leaf. Each segment was placed in a separate sterile moist chamber. This experiment was performed to determine whether the fungus was equally abundant in fruiting and nonfruiting shoots; that is, whether the fungus might possibly enter the flower and gradually work back into the older parts of the shoot and foliage. These segments were numbered 1 to 6, beginning at the basal end. On May 18 all six leaves were more or less discolored, numbers 1 to 4 less than the others. In all cases the discoloration spread from the base of the leaf toward the apex. All but No. 2 bore acervuli. On May 27 all the leaves were entirely discolored and almost covered with acervuli. The portions of the stem also showed acervuli. Since leaves 5 and 6, which were near the apical end of the shoot and youngest, became discolored slightly sooner than the older ones, it might, perhaps, be inferred either that they were infected earlier or that the tenderer tissues furnished more favorable conditions for rapid development.

On May 11 an apparently healthy fruiting shoot from the greenhouse was sterilized as usual and cut in segments which were placed in separate sterile Petri dishes. These segments were numbered 1 to 15, beginning at the basal portion of the shoot, as indicated in figure 1.

On May 18 the leaf on segment No. 1 was almost entirely covered with acervuli. The portion of the stem to which it was attached showed no signs of the fungus. Segment No. 2 showed no indication of the fungus on either leaf or stem; No. 3 showed a slight uniform discoloration of leaf only; No. 4 showed discoloration of the leaf along the midrib and a very few acervuli. Three young fruits on this portion were also discolored and acervuli abundant on the calyx of one; also on the leaf petiole. No. 5 showed discoloration of the basal portion of the leaf and of the stem only. Nos. 6 and 7 showed leaf and stem almost entirely discolored, but no acervuli. In No. 8 the basal portion of the leaf was discolored and a slight discoloration appeared on one side of the leaf, but no acervuli were present. No. 9 showed acervuli on the stem, but the leaf was not discolored. No. 10 had the entire leaf discolored. No. 11 showed the leaf almost wholly discolored, with the fruit black and bearing acervuli. On No. 12 the leaf and stem were almost entirely discolored, with acervuli at the base of the leaf. No. 13 showed the fruit completely discolored and acervuli present, but the leaf was not discolored. No. 14 showed the leaf entirely discolored, with acervuli on the cut surfaces of the stem. In No. 15 the leaf was almost entirely discolored, but no acervuli were present.

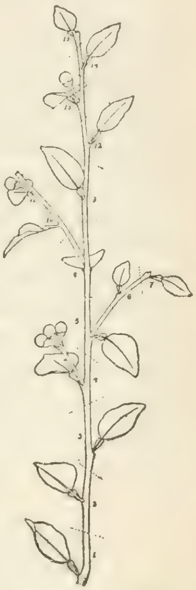

FIG. 1.—An apparently healthy fruiting branch of an orange taken from a greenhouse plant, divided into 15 parts as indicated, then washed thoroughly in corrosive-sublimate solution and kept in sterile moist chambers. *Glomerella cingulata* developed on all the leaves and fruit in such a manner as to indicate a probable origin from infection of the blossoms.

On May 20 leaves on Nos. 2 and 9 were still a normal color; all others, except 14 and 13, which were entirely discolored, showed abundant acervuli. Acervuli were present on all the fruits. On May 25 Nos. 2 and 9 had become discolored and showed abundant acervuli. Acervuli were also abundant on Nos. 11 and 13.

As a result of this experiment it will be noted that the fungus was present in all the leaves of the new growth as well as on the growth of the previous year. The fungus developed more rapidly on the older leaves. The early and vigorous development of the fungus in the young fruits and the leaves situated at their bases and the rather tardy development of the fungus in leaves remote from the blossoming shoots—that is, Nos. 2 and 9—seems to indicate a downward course of development of the fungus and infection by way of the blossoms, as shown by Rolfs (66) and Bessey (12).

CULTURES.

Numerous cultures have been made from conidia and ascospores obtained from orange leaves. Apparently healthy, vigorous orange leaves taken from greenhouse plants have frequently been treated with corrosive sublimate and placed in sterile moist chambers. Such leaves have almost invariably produced an abundant growth of acervuli, which is frequently followed by the development of perithecia with typical asci and ascospores. The time required for the development of perithecia is usually two to four weeks.

Poured plates made with conidia from leaves kept in moist chamber produced a growth very similar to that obtained from other hosts. The number, size, and distribution of the acervuli formed vary considerably. Setæ were not usually present in these plates. Several series of plates produced only conidia. Two showed a few peritheciumlike bodies, but no asci were found. Different tubes showed considerable difference in the appearance of the growth. In some it was light colored and scanty; in others, abundant and dark.

Cultures were made from conidia taken from an orange leaf received from Houston, Tex., March 10, which was treated as usual and kept in sterile moist chamber until March 29. Transfers of single germinating conidia to corn-meal agar tubes were made. The growth was of a smoky-brown color, resembling that of cultures from pomelo hereafter described. A few large acervuli were formed, but no perithecia, though perithecia were produced on leaves in moist chamber. Later, setæ were found in abundance.

CITRUS DECUMANA (POMELO).

Glomerella cingulata (Stonem.) S. and v. S.
Colletotrichum gloeosporioides Penz.

DEVELOPMENT ON LEAVES IN MOIST CHAMBER.

On March 28 apparently healthy leaves of the pomelo were taken from greenhouse plants and placed in sterile moist chambers. They soon became spotted and acervuli appeared. These were soon followed on darker areas of the discolored leaf by perithecia, which showed mature asci on June 20. Setæ were not found in the acervuli on these specimens.

On April 30 two apparently healthy leaves were taken from immediately below a cluster of young fruit; also an older leaf, from whose axil a fruiting shoot was produced. These leaves were treated as usual and placed in sterile moist chambers. On May 7 acervuli were found regularly scattered over the surface of the older leaf, but there were none on the two young leaves. On May 13 the base of one of the young leaves showed slight discoloration running up the midrib three-fourths of an inch. On May 15 both young leaves were discolored along the midrib. Acervuli developed abundantly on these young leaves later. On June 9 perithecia and asci were found on the old leaf. This experiment, like those with the orange, apparently showed the presence of the fungus in the tissues of both young and old leaves, but it is either more widely distributed in the old leaves or else develops in them more rapidly, as discoloration of the leaves and fructification of the fungus appeared sooner in most cases on old leaves.

On May 16 one of the young fruits about three-fourths of an inch in diameter was taken from the branch just above the two young leaves already referred to, the surface sterilized, and placed in a sterile moist chamber. On May 27 acervuli of Glomerella were found on the inside of the calyx and also on the fruit.

On March 6 other apparently healthy leaves, both young and old, were collected from a blossoming tree in the greenhouse, treated as usual, and placed in sterile moist chambers. Eight days later the 1-year-old and 2-year-old leaves showed abundant acervuli developing along the midrib, as indicated in Plate IV. The very young leaves in this instance showed no indication of the fungus. Ten days later the 1-year-old and 2-year-old leaves showed a number of discolored areas with perithecia. In this case the areas producing conidia and those producing perithecia were separate but contiguous, the two forms together almost covering the entire surfaces, as shown in Plate V. The young leaves now began to show discolored areas but no signs of fungous growth. On April 14 the youngest leaves were still free from any sign of fungus.

Other old leaves collected January 29 and treated as usual also developed an abundance of acervuli and perithecia.

CULTURES.

On March 16 cultures were made from conidia found on a fruit of pomelo received from Miami, Fla. Setæ were abundant in the acervuli on the fruit. The fungus grew rapidly, producing a smoky-colored growth like that in some of the cultures from the orange. Large acervuli were produced bearing a very few setæ. No perithecia were ever found in these cultures.

On May 14 other cultures were made from a pomelo fruit from Bonita, Cal. These cultures were made by transplanting portions of discolored spots or so-called "tear stains" from the fruit. The surface of the fruit was sterilized as usual with corrosive sublimate. The resulting growth was apparently pure and produced an abundance of acervuli and peritheciumlike bodies. These cultures were kept until August 13, but no asci or spores were found.

On June 17 corn-meal agar plates were poured, using conidia from acervuli surrounded by ascogenous perithecia from a leaf in moist chamber. These cultures all produced acervuli. They were kept until July 22 but showed no perithecia. No setæ or chlamydospores were seen in these cultures.

CULTURES FROM ASCOSPORES.

On June 25 poured plates were made with ascospores taken from a portion of a leaf in moist chamber which was producing perithecia only. A single ascospore was isolated and transferred to a slant agar tube.

On July 22 one plate showed a few perithecia with immature asci. No conidia were found. The tube culture from a single ascospore developed only a hyaline sterile mycelium and chlamydospores. Transfers from this tube to corn-meal flasks produced an abundant growth of white mycelium, which later became pinkish. On July 22 a very few spores, apparently conidia, were found. No typical acervuli or perithecia were produced in these cultures and it might possibly be suspected that the ascospores used did not really belong to Glomerella. They were, however, typical in appearance and morphological characters, and their identity could scarcely be doubted. The cultures from the ascospores on pomelo leaves did not produce, as is usually the case, many ascogenous fructifications. Only a few perithecia with spores were produced. Conidia were also scattered. No setæ were found, but chlamydospores were usually present. The ascospores from leaves in moist chamber varied from 18 to 23 by 4.5 to 6 μ. Asci were 60 by 10.5 to 12 μ. Paraphyses were found. The conidia from these cultures varied from 12 to 24 by 5 to 6 μ. Conidia from the leaves in moist chamber varied from 13.5 to 21 by 4.5 to 7 μ.

CITRUS LIMONUM RISSO. (LEMON).

Glomerella cingulata (Stonem.) S. and v. S.

DEVELOPMENT ON LEAVES IN MOIST CHAMBER.

Leaves of lemon taken from a plant in the greenhouse and showing small discolored dead spots bearing a few conidia were placed in a sterilized moist chamber. An abundance of acervuli soon developed over both surfaces of the leaves. A few setæ were found. No perithecia were produced on these leaves.

On January 29 another leaf spotted in the same way and showing acervuli was placed in a moist chamber. On February 19 the leaf was almost covered with acervuli. A few setæ were present. A few areas bore perithecia agreeing in every respect with those found on leaves of other citrus species under similar conditions.

On January 29 three leaves apparently perfectly healthy were sterilized as usual and placed in a sterile moist chamber. On February 11 acervuli were present on the largest leaf, occurring mostly along the midrib and the larger veins. On February 15 this leaf had grown much darker and many acervuli were present. The other two leaves showed no signs of a fungus except that the petiole of one bore a few acervuli. On April 7 abundant acervuli and perithecia had developed on all the leaves.

On April 30 two apparently healthy normal leaves were taken from a greenhouse plant just below an unopened flower bud, and a single leaf also was taken from the old wood lower down on the same branch. These leaves were sterilized as usual and placed in sterile moist chambers. On May 14 the old leaf showed discoloration extending from the base of the midrib to within half an inch of the tip, but no acervuli were present. On May 16 the end of the shoot from which the two leaves had been taken was cut off and placed in moist chamber. This shoot bore a young fruit about one-third of an inch in diameter, which had developed since the leaves were removed. The leaf next below these two was also taken and placed in moist chamber. On May 26 the old leaf showed acervuli. The two from below the unopened bud were still normal in appearance except for a slight discoloration at the base of the midrib extending up about three-fourths of an inch. The young fruit was also discolored, discoloration beginning at the stigma and working back. No acervuli or perithecia developed on the two young leaves and the fruit.

Since the foregoing was written, Essig (35) has recommended placing leaves in moist chamber to determine the presence of this fungus in lemon groves.

CULTURES.

On December 12 two plates were poured, using conidia from a lemon leaf in moist chamber. On December 17 an abundant growth was present in the two plates, which differed greatly in appearance, though both appeared to be pure cultures. In one the mycelium was colorless and uniformly distributed over the surface showing many minute acervuli. Brown chlamydospores had also formed against the surface of the glass. No setæ were found. In the other plate the mycelium was slightly colored and denser, with dark points suggesting the beginnings of perithecia. No spores were yet found in this plate. On January 14 acervuli were thickly and uniformly distributed over the surface of the first plate and a few large acervuli were present in the second plate. Setæ were also found in the second plate but none in the first. No perithecia developed in either. Subcultures made from both plates to flasks of corn meal made a growth which was identical in appearance and produced an abundance of pink acervuli. No perithecia were found.

On December 18 four plates were poured, using conidia from four separate acervuli from the same leaf in moist chamber. Numerous acervuli developed in all, showing a tendency to form about cavities in the agar where portions had been removed for subcultures. This behavior was also shown in plates made from the orange, but was not noticed in the other plates from lemon.

On May 28 cultures were made in five flasks of corn meal by transplanting a portion of the discolored epidermis, the so-called "tear-stain," of a lemon received from Bonita, Cal. The surface of the lemon had been sterilized by thorough washing with corrosive-sublimate solution. Appressoria or chlamydospores of Gloeosporium were found on the surface of the discolored skin. On June 2 the five flasks apparently contained pure cultures of Glomerella and were identical in appearance with those made in the same way from pomelo. Conidia were abundant, but no setæ were seen.

In discussing the diseases of the lemon caused by this fungus in California, Essig (35) states that the most satisfactory method of controlling them yet tried is by spraying with 4–4–50 Bordeaux mixture. This statement also accords with the results of Rolfs (66).

CITRUS NOBILIS LOUR. (MANDARIN).

Glomerella cingulata (Stonem.) S. and v. S.

DEVELOPMENT ON LEAVES IN MOIST CHAMBER.

On January 29 four apparently healthy leaves from greenhouse plants were treated as usual and placed in a sterile moist chamber. On February 11 acervuli of Glomerella were present on all, having developed first at the base of the midrib. On February 29 a few perithecia with ascospores were found. Perithecia of the same Glomerella were also found on spotted leaves from the same plant, which had been kept in moist chamber.

CULTURES.

On March 20 two tube cultures were made from acervuli on the leaves in moist chamber. These cultures produced a growth of normal appearance, with acervuli but no perithecia. On October 7 two plates were poured, using conidia from a leaf in moist chamber. These plates produced an abundance of acervuli. A very few setæ were found. Setæ had also been found on the leaves from which the cultures were made but they were not numerous. Subcultures from these plates also produced an abundance of acervuli, but no setæ were seen and no perithecia ever developed, though perithecia with immature asci were found on the leaves from which the original cultures were made.

On November 14 subcultures on corn meal were made from the tubes just described. Many large acervuli soon formed. The spore masses frequently ran together and formed pink masses covering about one-half the surface of the medium. Dark spots resembling perithecia were also present but no asci or ascospores could be found. These cultures were kept until the following March, but no fertile perithecia were found and no setæ were observed.

It will be noted that perfect perithecia and asci of Glomerella were frequently produced upon leaves of the various citrus species when placed in a moist chamber. It is therefore somewhat remarkable that in only one case, that of the pomelo, were we able to get perithecia to develop in cultures.

The fungus from all the citrus hosts showed very similar characters in cultures and can not be distinguished from that on most other fruits. When old the mycelium is usually of a dark greenish or smoky color. The form of the fungus growing on citrus species has apparently been described several times under different names in both its conidial and ascogenous conditions. The conidial form has been treated by Rolfs (66) and others as *Colletotrichum gloeosporioides* Penz. (63). To judge from the descriptions and figures, it has also received several other generic and specific names. The conidia have been found to vary from 11 to 19.5 by 4.5 to 6 μ. The ascospores vary from 16 to 19 by 4.5 to 6 μ.

The perithecial form has apparently been described under several different names, including *Physalospora citricola* Penz. It is also found under *Laestadia socia* Penz.

COFFEA ARABICA L. (COFFEE).

Glomerella cingulata (Stonem.) S. and v. S.

DEVELOPMENT ON LEAVES IN MOIST CHAMBER.

On December 4 leaves showing dead spots but no acervuli were taken from a coffee plant in the greenhouse. The surfaces were sterilized as usual and the leaves placed in a moist chamber. On December 30 acervuli and mature perithecia of Glomerella were found on these leaves. Setæ were present in the acervuli.

On January 29 two apparently healthy young leaves of the same age were treated in the same manner and placed in a sterilized moist chamber. On February 13 numerous acervuli were present on a discolored area, which extended downward from the tip of one of the leaves. The other leaf was entirely discolored but no acervuli were present. Later, perithecia of Glomerella were found associated with the acervuli on both leaves.

CULTURES.

On December 12 plates were poured using conidia from the leaves in moist chamber, on which perithecia developed later. A single conidium was located in one plate and transferred to a tube. On December 19 one plate had become contaminated and was discarded. The other contained a growth of the fungus of the usual appearance. Conidia were found. On December 26 acervuli were present in abundance in the tube and also in the plate. No setæ or perithecia were found. On January 8 two flasks of corn-meal agar were inoculated by transfer of conidia from the tube culture from the single conidium mentioned above. On January 20 an abundant greenish growth was present, and many dark bodies resembling perithecia were forming. Many acervuli were also present. No setæ were found and no perithecia ever matured sufficiently to show asci and ascospores.

On June 12 two slant agar tubes were made by transfer from the single conidium culture. These tubes produced a growth of the usual appearance and small acervuli formed, but no perithecia were ever found.

The growth and appearance of the conidial form from the coffee closely resembles that from other hosts, especially the Citrus species. Setæ and perithecia developed on the leaves in moist chamber but neither were found in the cultures made from the same leaves. The conidia from the leaves in moist chamber measured 13.5 to 16.5 by 5 to 6 μ. The conidia in culture varied from 15 to 18.5 by 4.5 to 6 μ. The ascospores from the leaves (Pl. I, figs. 14 and 14a) measured 15 to 18 by 5 to 6 μ. No paraphyses were found. The perithecial form found on the leaves suggested *Laestadia coffeicola* Speg. (86). The ascospores of this species are said to be obovate, and the measurements given are rather less than usual in *Glomerella cingulata.* Two species of Colletotrichum and two species of Gloeosporium have been described from coffee leaves. The descriptions of these species show no diagnostic characters sufficient to separate them satisfactorily. *Gloeosporium coffeanum* Delacr. (23) evidently refers to this species also.

COSTUS SPECIOSUS (KOENIG) SMITH (SPIRAL FLAG).

Glomerella cingulata (Stonem.) S. and v. S.

On January 30 portions of a leaf showing large dead areas were sterilized as usual and placed in a sterile moist chamber. On February 7 acervuli were found on these leaves, and on February 14 many mature perithecia of Glomerella were present. Asci and ascospores are shown in Plate II, figures 21 and 21a. No fungus of this kind in either stage could be found reported on this host.

On February 7 two tube cultures were made by a transfer of conidia from the leaf in the moist chamber, each culture from a different acervulus. On February 24 one large acervulus was present in one tube and a few large sterile dark bodies in the other. On July 7 a few acervuli were present in the second. The peritheciumlike bodies were still sterile and no asci were ever found. The general appearance of the growth in the tubes was much like that of the fungus from other hosts but somewhat lighter colored. The conidia from the specimens in moist chamber showed the usual variations in shape, and they varied in measurement from 12 to 18 by 4.5 to 6 μ. The conidia in cultures varied from 10 to 16.5 by 4.5 μ. The ascospores from the leaves in moist chamber showed the usual shape and varied from 15 to 21.5 by 5 to 6 μ.

CRATAEGUS SP.

Gloeosporium fructigenum Berk.

On December 12 three flasks of corn-meal agar were inoculated with spores from acervuli on a fruit of Crataegus which had been collected from a tree on the Department of Agriculture grounds and kept in moist chamber. The appearance of the acervuli and the decay of the fruit closely resembled that of the bitter rot of the apple. Conidia developed in these cultures and small dark bodies resembling perithecia were found in all the flasks, but no asci or ascospores were obtained.

CUCUMIS SATIVUS L. (CUCUMBER).

Gloeosporium lagenarium (Pass.) Sacc. and Roum.

On June 20 four plates were poured, using conidia from a cucumber leaf collected at Portsmouth, Va. Two days later transfers were made to slant agar tubes. On July 6 the tubes showed an abundance of acervuli with a dense growth of brown setæ. The cultures became contaminated and no perithecia were formed. No opportunity was offered for a further study of this form and its identity with the others described is therefore uncertain.

CUCURBITA PEPO L. (SQUASH).

Gloeosporium lagenarium (Pass.) Sacc. and Roum.

On October 17 four plates were poured, using conidia from acervuli on a squash. The conidia and acervuli were of the same general appearance as those from other hosts. Setæ were abundant. On October 22 conidia were abundant in all the plates, but were scattered, no distinct acervuli being formed. The conidia were unusually variable in size, ranging from 8 to 30 μ in length. In the thickly sown plates dark bodies suggesting perithecia were abundant. None of these dark bodies were present in the thinly sown plates. These peritheciumlike bodies always remained sterile. Chlamydospores were also abundant. The mycelium was light colored. Later, many acervuli with pale pink masses of conidia developed in the tubes, and also an abundance of the sterile perithecia. The cultures were kept until January 13, but no ascospores were ever found in the perithecia. The writers' cross-inoculations of squash with the fungus from the grape were successful, but this does not necessarily prove that the organisms are the same. No inoculations from the squash to other fruits were made.

CURCULIGO SP.

Glomerella cingulata (Stonem.) S. and v. S.

On January 30 a leaf of this plant from the greenhouse, showing an elongated dead area in the center which bore acervuli of Gloeosporium and immature perithecia, was sterilized in the usual manner and placed in a moist chamber. On February 3 many dark spots had appeared on the apparently healthy portions of the leaf. Acervuli soon appeared in abundance, and later, setæ were found. On February 17 many mature perithecia of Glomerella were also present. Neither form of this fungus appears to have been heretofore reported on this host.

On February 7 two tube cultures were made by transfer of conidia from the leaf in moist chamber. Acervuli with pinkish masses of conidia soon developed, also chlamydosporelike bodies. No perithecia appeared, and subcultures kept until January 23 produced none. The conidia on the leaves varied from 14 to 16.5 by 4.5 to 6.75 μ. The ascospores measured from 12 to 24 by 5.5 to 6 μ. An ascus and ascospores are shown in Plate II, figures 22 and 22a. No characters could be found either on the host or in the cultures to distinguish this fungus from that occurring upon various other hosts.

ERIOBOTRYA JAPONICA (THUNB.) LINDL. (LOQUAT).

Glomerella cingulata (Stonem.) S. and v. S.

On January 29 an apparently healthy leaf taken from a greenhouse plant which also showed some spotted leaves was treated as usual and placed in a moist chamber. On February 11 the leaf had turned dark brown and a few scattered acervuli were present. On April 8 acervuli were abundantly scattered over the surface. Setæ were sometimes present. No perithecia were found.

On the same date two spotted leaves from the same plant were placed in moist chamber. On February 12 abundant acervuli were present on these leaves. On February 20 perithecia of Glomerella were also found on the leaves.

Pure cultures made from acervuli from the leaves in moist chamber produced an abundance of typical acervuli, but no perithecia were ever found. The conidia from the leaves ranged from 12 to 18 by 4.5 to 6 μ; the ascospores from 15 to 19.5 by 5 to 6 μ. Neither stage of this fungus seems to have been described from this host heretofore. Asci and ascospores are shown in Plate I, figures 11 and 11a.

FICUS CARICA L. (FIG).

Glomerella cingulata (Stonem.) S. and v. S.
Colletotrichum carica Stevens and Hall.

On April 23 plates were poured with conidia from the fruit of a fig received from Georgia. These plates produced conidia. The general appearance of the growth was very similar to that of the fungus from other hosts. Subcultures in tubes produced large scattered acervuli. Setæ were present but not numerous. No perithecia were found in these cultures.

On May 29 streak cultures were made on slant agar tubes, using conidia from acervuli on a decaying fig received from Norfolk, Va. On June 4 no acervuli were found, but a few perithecia with asci not quite mature had appeared. Later, mature asci were found in one tube. These asci were slightly shorter and broader than the average. Some of them contained only two or four spores. Normal asci and spores were also present, however. Other tube cultures developed later an abundance of typical perithecia. The asci showed a greater variability in size than usual on other hosts. (See Pl. II, figs. 29 and 29a.)

On July 3 cultures were made using conidia from a stem of the fig from Norfolk. An abundance of acervuli were produced in these cultures. Setæ were sometimes present and sometimes apparently wanting. Chlamydospores were also found. The conidial form is evidently *Colletotrichum carica* Stevens and Hall (88), and it can not be distinguished, so far as the descriptions go, from several other species which have been published. This fungus showed no characters, either in culture or on the host, which would serve to distinguish it from forms occurring upon other species of Ficus as well as those on other fruits, especially the apple. This identity is also confirmed by the cross-inoculation experiments with apples and grapes described later. Edgerton (31), who apparently studied the same organism, also states that it does not differ in any way from the form on the apple. As a result of numerous measurements of asci and ascospores, we find the asci range from 53 to 115 by 10.5 to 15 μ. The ascospores vary from 13 to 21 by 5 to 7 μ.

FICUS ELASTICA ROXB. (RUBBER PLANT).

Glomerella cingulata (Stonem.) S. and v. S.
Neozimmermannia elasticae (Zimm.) Koord.

DEVELOPMENT ON LEAVES IN MOIST CHAMBER.

On January 14 apparently normal healthy leaves were taken from a greenhouse plant, treated as usual, and placed in a sterile moist chamber. On January 20 dark spots began to appear on the leaves. On February 14 the leaves were entirely discolored. No acervuli were present, but a few mature perithecia of Glomerella were found. Later, acervuli also developed.

On July 12 another apparently normal healthy leaf was treated in the same manner. On July 20 the under surface of the leaf had become light chocolate brown and was thickly covered with minute acervuli. Some larger, brighter colored ones were found on the petiole and about the midrib. No perithecia were found on this leaf. Many other leaves of this host have been treated in the same manner at different times, usually producing both conidia and ascospores.

CULTURES.

On February 11 streak agar tube cultures were made, using conidia from a leaf in moist chamber. On April 8 perithecia were abundant in one tube, being mostly aggregated in masses about the bases of old acervuli. Appressoria were also abundant on the surface of the glass in the upper part of the tube. Subcultures on corn meal in flasks produced an abundance of fertile perithecia also.

On April 1 bits of leaf bearing mature perithecia with ascospores were transferred to flasks of corn meal. On April 26 an abundant growth of conidia and also mature perithecia were found. Setæ were sometimes found in the cultures but not regularly.

Koorders (54) has investigated this form of the fungus as it occurs in Java. He refers the perithecial form to a new genus, Neozimmermannia. There is, however, nothing in his description to separate his fungus from Glomerella and specimens of our plant submitted to Dr. Koorders for examination were said by him to be identical with his fungus. The conidial form has been called *Gloeosporium elasticae* Cke. and Mass. It can not be distinguished from the forms found on other *Ficus* spp. The asci were found to vary from 52 to 82.5 by 7.5 to 12 μ. Plate II, figures 18 and 18a, shows an ascus and ascospores.

FICUS LONGIFOLIA-SCHOTT.

Glomerella cingulata (Stonem.) S. and v. S.

DEVELOPMENT ON LEAVES IN MOIST CHAMBER.

On November 18 two leaves of *Ficus longifolia* showing small dead areas were taken from a greenhouse plant, treated as usual, and placed in a sterile moist chamber. On December 6 numerous acervuli were present, producing masses of salmon-colored conidia. No setæ were found at this time. On January 4 setæ were present and also perithecia with mature asci and ascospores.

On January 29 another apparently healthy, normal leaf was taken from a greenhouse plant, sterilized as usual, and placed in moist chamber. On February 15 the leaf showed discolored spots of a dark-brown color and a few acervuli were found. Perithecia were also present, especially along the midrib. Some were single and others aggregated in groups. Mature asci were seen. The perithecia and ascospores were apparently identical with those obtained from other species of Ficus and could not be distinguished from the forms of Glomerella from various other hosts. Asci and ascospores are shown on Plate II, figures 19 and 19a.

CULTURES.

On December 12 plates were poured, using conidia from leaves in moist chamber. The growth was of the usual character and produced a few acervuli, but no perithecia ever appeared.

On February 3 subcultures from these plates were made in flasks of corn meal. The course of development was as usual, and on February 25 acervuli with pinkish masses of conidia were present. Peritheciumlike bodies were also found on the sides of the flask, but no asci or ascospores could be discovered.

On April 28 plates of different dilutions were poured, using conidia from the cultures just described. On May 4 the plate most thinly sown showed a considerable number of acervuli. The next plate, in which more conidia were used, showed very few acervuli. The third plate, in which a still larger quantity of spores was used, showed many scattered conidia but no acervuli. In the cultures where numerous spores were sown, acervuli were much fewer than in those where the spores were more scattered. This behavior may perhaps have some direct relation to the greater quantity of nutriment available in the case of the thinner sowings than in the other. No perithecia were ever found in these cultures, although perithecia were present on the leaves from which the cultures were made. This may possibly have been due to the fact that both fertile and sterile strains were present on the leaves and the conidia used happened to be taken from acervuli belonging to a nonperithecium-producing strain.

Conidia from leaves in moist chamber varied from 15 to 20 by 5 to 6 μ, averaging slightly thicker than in most of the other forms. Conidia in plates varied from 13.5 to 16.5 by 5 to 6 μ. Ascospores ranged from 15 to 22 by 4.5 to 6 μ. No paraphyses were seen.

GINKGO BILOBA L.

Glomerella cingulata (Stonem.) S. and v. S.

Fallen leaves of this plant taken from the grounds of the Department of Agriculture were washed as usual and placed in a sterile moist chamber. In a short time acervuli of Gloeosporium formed on the leaves.

On November 13 potato-plug cultures were made by transferring conidia from the acervuli on the leaves in the moist chamber. On

November 23 an abundance of white mycelium was present in the cultures, also a number of black patches looking like areas of developing perithecia. On December 9 a flask of corn meal in which a subculture had been made from a potato plug showed an abundance of mature perithecia with asci and ascospores, which appeared identical with those of the Glomerella from other hosts.

On December 13 three plates were poured, using ascospores from the flask culture just described. On December 19 all the plates showed perithecia and also conidia.

On January 4 other plates were poured from the same material apparently containing ascospores only. Conidia developed in a few days, and perithecia also appeared later.

On January 23 subcultures were made in flasks of corn meal. On February 9 an abundance of perithecia and mature asci were present. Very few conidia were found. The fungus used in all these cultures appeared to belong to a race in which the perithecial form predominated. So far as known, no organism belonging to this group has heretofore been described or reported from the ginkgo. Plate II, figures 27 and 27a, shows an ascus and ascospores from leaves of this host.

GLEDITSIA TRIACANTHOS L. (HONEY LOCUST).

Glomerella cingulata (Stonem.) S. and v. S.

On November 24 cultures in flasks of corn meal were made by transferring conidia from an acervulus on a leaf taken from a locust tree on the grounds of the Department of Agriculture. A little leaf tissue was also included in this transfer. On December 1 all of the cultures were identical in appearance and showed an abundant growth of young perithecia of Glomerella with asci but no fully mature ascospores. No acervuli or conidia were seen. On December 9 there was an abundance of mature perithecia and ascospores present. No distinct acervuli or conidia were positively identified in these cultures, though the cultures were derived from conidia or conidia-bearing mycelium from the leaf of the host. On January 4 poured plates were made, using ascospores from the flask cultures just mentioned. These ascospores germinated readily and produced a growth of the usual appearance. On January 8 conidia were found in these cultures. On January 10 two more plates were poured, using ascospores from the same cultures. These spores germinated, and on January 15 perithecia were found at many points in the plates. This strain also showed a great predominance of perithecia. In other respects it appeared identical with the Glomerella from other hosts. An ascus and ascopores from cultures from this host are shown in Plate II, figures 20 and 20a.

GOSSYPIUM HIRSUTUM L. (COTTON).

Glomerella gossypii Edge.
Colletotrichum gossypii South.

DEVELOPMENT ON BOLLS AND STEMS IN MOIST CHAMBER.

On February 20 leafless tips of cotton stems received from Lome, Togoland, western Africa, were treated as usual and placed in sterile moist chamber. These specimens showed dried whitish patches, suggesting old acervuli of *Colletotrichum gossypii*, but no conidia could be found. On February 23 acervuli with the characteristic brown setæ of this species were present on the stems. Transfers from these acervuli to flasks of corn meal produced an abundant growth of conidia and a dark mycelium but no perithecia.

On May 7 eight apparently healthy bolls about three-fourths grown were taken from a single plant in the greenhouse. The surface was sterilized as usual and the bolls placed in a moist chamber. On May 22 these bolls were more or less discolored, but no fungus was visible. On May 25 one of the largest bolls was almost completely covered with acervuli of *Colletotrichum gossypii*. On June 17 four other bolls also showed acervuli. As these bolls had been in the same chamber with the other, it is possible that infection came from the first boll.

On June 22 five other bolls of various ages were treated in the same way, but no Colletotrichum developed on any of them. These experiments would appear to indicate that the fungus on the cotton is able to live in a dormant or hibernating condition, as has been found to be the case with most of the other forms.

CULTURES.

On October 28, 1905, sections from a diseased cotton boll were transferred to flasks of corn meal. These all developed a growth resembling that of the cotton anthracnose, and on November 23 one flask showed acervuli with pink masses of conidia and also perithecia with ascospores not quite mature. All the other flasks showed a luxuriant growth of a white mycelium and conidia. Transfers were made from a flask producing perithecia. These also produced perithecia and ascospores.

Tests were also made of the effect of corrosive-sublimate solution, 1 to 1,000, on conidia of this fungus, the spores being treated from five to seven minutes and then transferred to poured plates. Check plates were made at the same time to determine the vitality of the spores. The checks grew luxuriantly, but no growth appeared in the plates sown with spores treated with corrosive sublimate, indicating that they had all been killed.

The appearance of this fungus in cultures is quite characteristic and remarkably uniform. The mycelium usually becomes dark colored rather early in its growth and the acervuli quite constantly produce an abundance of setæ which occasionally bear conidia, evidently indicating the derivation of the setæ from ordinary conidiophores. The production of the perithecial form of this fungus was first reported by the writers (75) in 1907 from the cultures described above. Later, Edgerton (29), 1909, reported finding the perithecial form on cotton bolls in Louisiana and named the fungus *Glomerella gossypii*. Since this fungus appears to possess certain morphological characters both under natural conditions and in cultures sufficient to separate it from its near relatives, it is apparently deserving of specific rank. Cross-inoculation experiments also seem to sustain this conclusion. An ascus and ascospores are shown in Plate I, figures 12 and 12a.

HEDYSCEPE SP. (PALM)

Glomerella cingulata (Stonem.) S. and v. S.

Acervuli and perithecia with ascospores agreeing in all essential particulars with those of Glomerella as it occurs on other hosts were found on leaves of this host in the Department greenhouse. No pure cultures were obtained of this form. An ascus and ascospores from this material are shown in Plate II, figures 26 and 26a.

LIGUSTRUM VULGARE L. (PRIVET).

Glomerella cingulata (Stonem.) S. and v. S.
Gloeosporium cingulatum Atk.

DEVELOPMENT ON LEAVES AND STEMS IN MOIST CHAMBER.

Diseased leaves and stems of privet sent from Digby, Nova Scotia, and received September 30, showed fertile perithecia agreeing with the description of *Glomerella cingulata* except that the measurements of the ascospores were slightly less than those given by Stoneman (89). A single acervulus bearing conidia of the usual form and also showing a few setæ was also found on a sunken light-brown spot on one stem. This twig and others showing dark swollen points suggesting immature acervuli or perithecia were placed in a sterile moist chamber.

On October 4 mature perithecia had developed on this material and ascospores were oozing from the ostioles in light pinkish masses. Conidia developed a little later on the leaves and stems also. Perithecia also developed on the leaves in moist chamber.

CULTURES.

On October 16 plates were poured, using conidia from a leaf in the moist chamber. On October 24 many dark acervuli were present, the color being due in part to the dark basal hyphæ and in part to the brown setæ. On November 6 many mature perithecia were also found in the plates. Subcultures made by transfer of conidia from these plates also developed perithecia. Several other cultures made from the same material produced both acervuli with setæ and mature perithecia with ascospores. In some of the cultures the perithecial form predominated.

In order to study the behavior of the fungus with reference to its variability in different generations under practically the same conditions, a pure line or strain was isolated by taking single conidia from a plate which had also produced ascospores. These were transferred to tubes of corn-meal agar. The plates from which they were taken finally developed acervuli with setæ; also some perithecia. Only one of the tubes containing a single conidium gave a pure culture; the others became contaminated. This one produced several rather definite areas of mature perithecia and a few acervuli bearing pinkish masses of conidia. The second generation was obtained by transfers of conidia from this tube to two others. One of these tubes produced an abundance of perithecia, while the other contained fewer perithecia and a greater development of mycelium. Conidia were present in both, but were few and did not form in large, distinct acervuli. These cultures had the same general appearance as the first generations from ascospores described below.

On October 18 pure-line cultures were started, using a single ascospore from a poured plate made from ascospores derived from the original twigs. This culture developed a rather scanty growth of light-colored mycelium with but few conidia. Later, a few perithecia were found, but asci had not developed. The culture became contaminated with bacteria and was discarded.

One tube, to which a whole ascus had been transferred, produced a few inconspicuous acervuli with setæ and later an abundance of perithecia with mature asci and spores. Transfers were made from this tube, producing the second ascospore generation. A few conidia developed but no distinct acervuli. Mature perithecia and ascospores were also formed. The perithecia were not evenly distributed, as was sometimes the case in other cultures, especially those from the form on *Persea gratissima.*

Generation 3 was started by transfer of perithecia from generation 2. This culture produced an abundance of perithecia and a few conidia without acervuli. The appearance of the cultures was very similar to that of generation 2.

For generation 4, six transfers were made of perithecia from generation 3. These soon developed numerous small acervuli with setæ. Few perithecia formed in these cultures. Other cultures made at the same time from ascospores from another series from this host made a growth of quite different appearance, no acervuli and very few conidia being formed. Few perithecia appeared. A further discussion of the pedigreed cultures will be given later.

Five transfers of single conidia were made from a plate subculture originally from a single ascospore culture. The growth produced in the five tubes was identical in appearance. A few acervuli developed near the point of inoculation and concentric rings of perithecia extended to the base of the culture. No asci were produced, however, so far as could be found. Plates poured from conidia from one of these tubes developed an abundance of conidia, but no distinct acervuli were formed. Chlamydospores and perithecia were present, but, as in the preceding generation, no asci developed.

The spores of this form, both ascospores and conidia, were very variable in size. The conidia in cultures ranged from 12 to 33 by 4.5 to 7 μ. On the host they ranged from 12 to 21 by 4.5 to 6 μ. Ascospores from the host ranged from 13.5 to 23 by 4.5 to 5.5 μ. Ascospores from cultures varied from 16.5 to 24 by 5 to 6 μ.

Miss Stoneman (89) gives the ascospore measurements of this species as 20 to 28 by 5 to 7 μ, which still further extends their range of variation. Unless the study of a vast number of spores from various localities should establish a constant mean spore measurement decidedly different from that found in Glomerella from other hosts, there seems to be no way of distinguishing this plant specifically from it. An ascus and ascospores are shown in Plate II, figures 17 and 17a.

MALUS SYLVESTRIS MILL (APPLE).

Glomerella cingulata (Stonem.) S. and v. S.
Glomerella rufomaculans (Berk.) S. and v. S.
Gloeosporium fructigenum Berk.

Several attempts were made to develop this fungus from twigs of the 1-year-old growth taken from trees which had been badly affected with bitter-rot. In the 12 trials made no Gloeosporium was obtained in the cultures.

The production of the perithecial form from this host has already been described by several writers, both on the host and in pure cultures. It is therefore unnecessary to give a detailed account of our work on this point. Fertile perithecia of Glomerella are often produced on apples which have been attacked by bitter-rot; and they are also frequently obtained in cultures, though their production can not be depended upon in any particular strain. Here, as in forms from other hosts, there appear to be fertile and sterile strains so far as the production of ascospores is concerned. Fertile perithecia have been produced in flasks of corn meal by transplanting portions of an apple taken from just beneath the skin where ascogenous perithecia were formed, and subcultures from these have continued to produce perithecia.

Leaves from trees badly affected with bitter-rot produced acervuli of Glomerella in abundance when kept in a sterile moist chamber. From this host, as from others, a strain of the fungus is sometimes obtained which produces peritheciumlike bodies in which no ascospores develop.

CULTURES.

Fifteen tube cultures, made September 14, using conidia from acervuli on different bitter-rot spots on a Willow Twig apple from Vienna, Va., all developed perithecia but no acervuli. In five of the tubes the perithecia were fertile, producing asci and ascospores. The other 10 produced only immature or sterile perithecia. Apples inoculated with ascospores from these cultures developed bitter-rot, followed by the production of fertile perithecia but no acervuli, indicating in this strain the great predominance of the perithecial form. Cultures made from apple leaves from West Virginia, obtained from Mr. Rand, produced perithecia with asci somewhat smaller than usual, as shown in Plate III, figure 39. Cultures of this form grown on sterile apple twigs also showed a few brownish ascospores.

The spore measurements of Glomerella as found on this host and in cultures are as follows: Asci from fruit in moist chamber 69 to 78 by 6 to 10.5 μ, in cultures 54 to 110 by 7.5 to 13 μ; ascospores from apple 15 to 21 by 4.5 to 6 μ; ascospores in cultures 13.5 to 21 by 4.5 to 6 μ. Variations in the asci from this host are shown in Plate III, figures 35 to 39. Plate I, figures 3 and 3a, also shows an ascus and ascospores of the same.

CHROMOGENIC FORM.

On November 16 four plates of corn-meal agar were poured from a single acervulus of Glomerella from an apple from Vienna, Va., which had been kept in moist chamber in the laboratory. These cultures produced an abundance of acervuli and chlamydospores. In the dilute plates the acervuli were numerous; in the thickly sown plates acervuli were almost entirely wanting and the conidia scattered. These cultures when about a week old began to take on a pinkish color, the color apparently being developed in the agar and not in the mycelium of the fungus. Four tubes inoculated by transfer of spores from four different acervuli from this same plate were made to determine whether this chromogenic character was possessed by other acervuli and whether it persisted. Four days later a slight pinkish tinge was visible in all the cultures, and at the end of a week the agar had become a decided pink color, and acervuli were present in all the tubes.

On November 24 three more plates and three tubes were made from an acervulus on the same apple used in the previous cultures. From the poured plates six transfers of single germinated conidia were made to tubes.

On November 28 three cultures made by direct transfer from an acervulus on the same apple showed the same pink color observed in all previous cultures from this apple. Acervuli were present. There was no color in the plates at this time, though acervuli were present.

On November 30 the pink color was very conspicuous in the six single-spore cultures, and the cultures were practically identical in appearance with those in the other tubes. The appearance of the pink color in all the pure single-spore cultures completely dispelled the natural suspicion that the first cultures might have been contaminated. These cultures, though kept for several months, never developed any dark mycelium, the growth of hyphæ being white or only slightly grayish. The cultures differed in this respect from most other cultures from apples and other hosts, which usually produce more or less of a dark greenish or smoky-colored mycelium, especially when old. Chlamydospores were present in these cultures, but differed slightly from the usual form, many being large and regular. In the following June transfers were made from these old cultures, which were still living, to slant agar tubes. The growth was very slow. On September 4 conidia were present, and the agar showed a slight pinkish color. One tube showed little or no color. Other transfers from a tube showing color made a more abundant growth of acervuli and showed more of the pinkish color.

On December 4 two sound apples were inoculated by puncture, using conidia from one of the single-spore cultures from this chromogenic form. The surface of the apples was carefully sterilized by washing as usual, after which they were placed in a sterile moist chamber. Decay began at the points of inoculation in a few days, and on December 17 the decayed areas on both of the apples were more than an inch in diameter and slight pustules, apparently young acervuli, were developing on the skin. On December 26 acervuli having all the characteristics of Glomerella were numerous on the decayed spots. The conidia were extremely variable. No setæ were found.

On January 4 and 5 plates were poured, using conidia from one of the inoculated apples just described. Four transfers were made of single germinating spores to tubes of agar. The general appearance and development of the fungus in these tubes was very similar to that in the previous cultures of this chromogenic form. One culture failed to grow; the other three soon began to show the pink color in the medium. The color in these cultures never became quite so pronounced as in some others.

On January 6 six tube cultures were made by transfer of conidia from a single acervulus in one of the single-spore cultures just described. Three were on prune agar and three on a synthetic medium. The cultures on prune agar made rapid growth, produced an abundance of acervuli, and the medium became a decided pink color. No perithecia or peritheciumlike bodies ever appeared in any of these cultures. The constant white or grayish color of the mycelium, the chromogenic character of the fungus, and the variation in the conidia suggested very strongly the possibility that we were dealing with an organism different from the common bitter-rot fungus of the apple. The conidia were very variable in size. Those which were scattered were rather smaller than usual, and those borne in the acervuli were large and more uniformly pointed at the ends. As no perithecial form was found on the fruit from which the cultures were obtained nor in any of the cultures, it is possible that this may represent a distinct species or variety.

EUROPEAN FORM.

Schneider-Orelli (69) has recently reported the results of comparative studies of the conidial stage of *Glomerella cingulata* sent from Virginia and *Gloeosporium fructiginum* Berk. found on apples in Switzerland. He finds very little difference in the morphological characters of the American and European forms. A comparison of their physiological characteristics showed a difference of 5 degrees centigrade for minimum, maximum, and optimum growth. The minimum temperature at which growth occurred in the European material was 5°, the optimum temperature 23°, and the maximum temperature 27° C., while the minimum, optimum, and maximum for the American material was found to be 5 degrees higher, or 10°, 27°, and 32° C., respectively. Whether this difference would hold good with other races and strains from the two countries is a question. The writers have carried out no such comparative studies but have reason to suspect that further work in this direction might show that this physiological character is also variable in both the American and European forms. Little difference was found in the production of rot caused in stored apples when inoculated with the two forms. According to the writer just cited, as well as other European pathologists, the bitter-rot fungus is not common in Europe and where present causes very little loss. It seems probable that this is due, in great part at least, to the less favorable climatic conditions prevailing in parts of Europe where apples are mostly grown, the low average maximum summer temperature being perhaps the chief factor as compared with the average summer temperatures in the parts of the United States where the discase is most serious. As has been pointed out elsewhere in this paper, there is evidence to show considerable difference in the virility of different strains of the fungus from different sources in this country, and this fact may explain the difference in destructiveness of the disease in localities where climatic conditions are apparently equally favorable and the disease is present.

MANGIFERA SP. (MANGO).

Glomerella cingulata (Stonem.) S. and v. S.

On May 6 leaves and stems of mango received from Hallandale, Fla., showing acervuli of Gloeosporium, were placed in a moist chamber. On May 18 perithecia with immature asci and numerous acervuli were found on the leaves, and many acervuli were also present on the stems. In the absence of mature ascospores there is a possiblity that the perithecial form associated with the conidia was not Glomerella, but this is not probable.

On May 29 plates were poured, using conidia from the mango leaves in moist chambers, and later, single germinating conidia were transferred to tubes. These cultures produced an abundance of large acervuli with pink spore masses, and a few setæ were found. The general characters of the growth were as in the forms from other hosts, though the mycelium varied somewhat in quantity and color. No perithecia ever occurred in these cultures, though immature perithecia developed on the leaves from which the cultures were made. The conidia from a single acervulus in one of these cultures varied from 12 to 25.5 by 3.5 to 6 μ.

Three species of Gloeosporium have been described from the mango, *G. mangae* Noack (61), *G. mangiferae* Henn. (46), and *G. raciborski* Henn. So far as the descriptions go they can not be satisfactorily separated. The extremes in the spore measurements given for these three species are nearly all included within the range of the measurements found in the single acervulus just referred to, while setæ were present in some acervuli and wanting in others.

MARANTA ARUNDINACEA L. (ARROWROOT).

Glomerella cingulata (Stonem.) S. and v. S.

On January 29 a portion of a leaf of this species, showing a small dead area, was taken from a greenhouse plant, treated as usual, and placed in a sterile moist chamber. On February 7 acervuli had developed, and a little later immature perithecia were found. Tube cultures were made by transfer of conidia from the leaf just described. These cultures produced a growth of the usual appearance of Glomerella. Numerous acervuli with pinkish masses of conidia were formed. Though the cultures were kept for nearly a year, no perithecia were ever found in them. The fungus agreed in all essential particulars with *Glomerella cingulata.*

MUSA PARADISIACA SAPIENTUM (L.) KUNTZ. (BANANA).

Gloeosporium musarum Cke. and Mass.

Cultures of this fungus, which is frequently found upon decaying bananas, have been made at different times. The growth and appearance of the fungus in cultures in most cases is somewhat different from that of the other forms grown. A slight amount of white mycelium generally appears at first and soon becomes dotted with small, dark bodies which suggest perithecia, but when carefully examined they prove to be small acervuli. The acervuli usually develop in great numbers and, being crowded, produce large continuous masses of salmon-pink spores. Chlamydospores were very abundant in some cultures. No setæ were ever found. A few dark perithecium-like bodies were occasionally found in old cultures, but no asci or spores ever developed.

Spore measurements obtained from conidia in a single acervulus in a culture were 9 to 28 by 4.5 to 6.5 μ. In other cultures conidia were found reaching 34 μ in length and 8.5 μ in thickness. With no knowledge of the perithecial stage of this form, it is not possible to make any positive statements in regard to its identity with the species of Glomerella from other hosts. In some cultures it showed essentially the same characters and appearance as in the forms from other hosts, while in others, as mentioned above, it showed rather different characters.

Most of the attempts to transfer the Gloeosporium on banana to other fruits have been failures. Laubert (56) had no success in inoculations from the banana to apples, though Cobb (21) reports success in producing bitter-rot of pears and quinces with the banana fungus.

OXYCOCCUS MACROCARPUS (AIT.) PERS. (CRANBERRY).

Glomerella cingulata vaccinii Shear.

This fungus has been found at various times on both fruit and foliage of the cranberry and has already been reported on by the senior writer (74). More recently the perithecial form has been again obtained in a number of cases from fruit collected in Massachusetts. Cross-inoculation experiments with apples have given negative or uncertain results. In one case a small decayed spot appeared, and a few acervuli formed. It is possible that this variety would adapt itself to another host in a few generations as some of the other forms have done.

PERSEA GRATISSIMA GAERTN. F. (AVOCADO).

Glomerella cingulata (Stonem.) S. and v. S.

DEVELOPMENT ON LEAVES IN MOIST CHAMBER.

On January 15 apparently healthy leaves from a greenhouse plant with the surfaces sterilized as usual were placed in a sterile moist chamber. Dark spots soon appeared on these leaves, and on February 3 an abundance of acervuli with pinkish masses of conidia were present. No perithecia were found.

On July 1 other leaves of normal appearance from the greenhouse were treated in the same manner as the preceding. On July 26 numerous acervuli were present and also perithecia with immature asci. Later, mature asci and spores were found.

On December 30 leaves showing small dead areas were taken from the same source and treated in the same manner as above. On January 7 abundant acervuli with setæ were found on one of the leaves. On January 17 a few mature perithecia were found on the same leaf. They were characterized by unusually long beaks. Later, acervuli and perithecia developed on the other leaf also.

CULTURES.

On December 18 five plates were poured, using conidia from a single acervulus on avocado fruit received from Miami, Fla. A few setæ were present in this acervulus. Three single germinating conidia were transferred to tubes. On January 5 both plates and tubes differed in appearance from the earlier cultures from Persea, especially in the scarcity, or almost complete absence, of conidia. A few dark stromatic bodies were present in the plates, but no perithecia. A very few acervuli finally developed in the tubes, but no setæ or perithecia were found.

On January 6 plates were poured, using conidia from acervuli which had developed upon an apple inoculated with conidia from the same avocado fruit. A loose white growth of mycelium was produced, bearing very few conidia. These cultures differed conspicuously from plates poured at the same time, using conidia from the avocado fruit. The growth was much more abundant in the latter case and the conidia more numerous, suggesting the possibility that the fungus had lost some of its vitality through its development on the apple. A few setæ were found later and a few apparently immature perithecia finally developed.

On January 6 more plates were poured, using conidia from the same avocado fruit. A luxuriant white growth soon developed, producing an abundance of conidia but no distinct acervuli. Transfers to tubes from these plates produced acervuli with an abundance of setæ and a few apparently immature or sterile perithecia.

On April 30 other plates were poured, using conidia from a leaf taken from a plant in the greenhouse. Germinating conidia were transferred from one of these plates to two tubes. On May 15 both the tubes and the plate showed acervuli with pinkish masses of conidia, and a number of areas of fertile but immature perithecia were found in the plate. The conidia were much more abundant in the tubes than in the plates. Later, a few fertile perithecia developed in the tubes. Transfers of conidia from these tubes to flasks of corn meal grew rapidly and in about a week perithecia formed, but no conidia could be found. A little later the perithecia matured and gave an abundance of ascospores. Plates poured, using these ascospores, produced few conidia and no distinct acervuli, but numerous chlamydospores and an abundance of fertile perithecia.

Many other transfers from this material, both of conidia and ascospores, showed considerable variation in the appearance of the growth and the relative development of conidia and perithecia. Perithecia usually predominated in the plates, whether started from conidia or ascospores. Conidia were more frequently scattered and hyphomycetous than in distinct acervuli. Various attempts were made to determine whether the amount of culture medium used in the plates or the thinness and thickness of the sowing of the spores had any direct relation to the production of ascospores or perithecia. In the case of a strain of the fungus which normally produced perithecia it appeared that perithecia were more numerous and conidia less so in plates which were thickly sown. In about a dozen cases perithecia were found forming along the sides of cotton fibers which happened to be present in the agar. This suggested that the resistance of some solid substance might possibly stimulate their formation. In many cases, especially in this form from Persea, the perithecia showed a tendency to develop about an acervulus, forming a small cluster or group, with the acervulus as a stromatic base.

Two series of generations of pure-line cultures were started from the same original culture of this organism. In one case ascospores only were used and in the other case conidia only. The ascospore cultures were carried through seven generations on the same medium and under practically the same conditions of growth and environment. The conidial cultures were carried through 23 generations and their behavior was compared with the generations from ascospores, as well as with duplicate cultures of each generation. An account of these cultures will be given later under the head of "Pedigreed cultures."

The conidia from leaves in moist chamber varied from 11 to 19.5 by 4.5 to 5.5 μ. Conidia from cultures varied from 12 to 18 by 4.5 to 6 μ. Ascospores from leaves averaged about 18 by 6 μ. Those in cultures ranged from 13.5 to 22.5 by 4.5 to 6 μ. An ascus and ascospores are shown in Plate I, figures 10 and 10a. Bessey (12) and Rolfs (66) have referred the conidial form of the fungus on avocado to *Colletotrichum gloeosporioides* and Bessey (12) reports successful cross-inoculations from citrus fruits and mangos, thus confirming its identity physiologically as well as morphologically with the organism on the orange, which in turn can not be satisfactorily separated from the form on privet, apple, etc. According to the authors cited, infection takes place through the flowers. Higgins (47) has recently described a serious disease of avocado in Hawaii which he considers as probably due to Gloeosporium. Its effect upon the plant, attacking as it does flowers, foliage, and shoots, is the same as that of the organism just described.

PHASEOLUS VULGARIS L. (WAX BEAN).

Glomerella lindemuthianum Shear. n. comb.
Colletotrichum lindemuthianum Sacc. and Magn.

Numerous cultures of the bean anthracnose have been made at different times and in different seasons. The cultures from conidia in most cases have been rather uniform in appearance and behavior, agreeing with the descriptions given by Atkinson (3), Whetzel (95), Edgerton (30), and others. In 16 slant agar tubes made November 3 from different acervuli on 5 bean pods the growth soon became very dark colored. This appears to be quite a constant characteristic of this species, and all the cultures made were practically identical in appearance during their growth. No perithecia were produced in these cultures.

The acervuli varied greatly in number and size in different cultures, and setæ, though usually present, were not numerous. Many chlamydospores were also found in some cultures. Cultures from single conidia, showing the usual appearance of the fungus, are shown in Plate VII.

In December cultures were made in flasks of corn meal by transfer of conidia and a bit of tissue from a bean pod bearing acervuli of the bean-anthracnose fungus. Later, all of the flasks showed good perithecia and asci, but conidia were scarce or wanting. An ascus and ascospores are shown in Plate I, figures 13 and 13a. These cultures finally became contaminated and were discarded. Plates were previously made from them, using the crushed perithecia and asci. The ascospores germinated readily and produced a dense growth of mycelium of the usual appearance. No conidia were found in these plates. Other plates poured from the same ascospore material produced the same typical mycelial growth; and at the end of 12 days perithecia were present in great numbers, but no conidia were found. Other plates were poured on March 16. A single ascospore transferred to a tube and afterwards to a flask of corn meal produced the usual growth of mycelium; and on April 3 an abundance of perithecia with mature asci were present, but no conidia were seen.

This is the only case in the writers' experience with these organisms in which cultures made from ascospores have apparently produced no conidia or if they were formed they were so few in number that they escaped observation. It does not appear, however, that there can be any doubt about these perithecia belonging to the bean anthracnose. The cultures were originally started from the conidial form on a bean pod and conidia were found in the first cultures with the perithecia. The perithecia, asci, and all the morphological characters of the fungus agree with Glomerella, as will be observed by comparing Plate I, figures 13 and 13a, and also the measurements of conidia and ascospores. The fact that conidia were few in the original culture and wanting in others apparently shows only an extreme variation in this particular, as cultures from different hosts have shown a great degree of variability in respect to the relative abundance of the different spore forms in any race or strain, and there seems to be a general tendency on the part of cultures from ascospores to produce fewer conidia than do those which originate from conidia. In the case of the form from the gooseberry (*Ribes oxyacanthoides*), described later, the predominance of perithecia was also very striking. Conidia, though present, were usually scattered or formed minute acervuli which were very inconspicuous and easily overlooked, whereas the perithecia were produced in great numbers and were very conspicuous.

In one other series of cultures from conidia from a bean a few small peritheciumlike bodies were found at the edge of the culture, but no asci or ascospores were obtained.

The appearance and behavior of this organism in cultures, as well as the failure of cross-inoculation experiments, apparently shows it to possess sufficiently well-marked characteristics to justify its separation as a distinct species, though the perithecial form taken alone could be distinguished with great difficulty, if at all, from that obtained from other hosts. It is tentatively named *Glomerella lindemuthianum* Shear.

PHORMIUM TENAX FORST.

Glomerella cingulata (Stonem.) S. and v. S.
?*Physalospora phormi* Schröt.

On April 1 slant agar tubes were inoculated by transfer of spores from an acervulus of Gloeosporium on a leaf of Phormium from the greenhouse. The growth in these tubes had the same general appearance as that of most other forms of this species grown from other hosts. A few acervuli formed with pinkish masses of conidia. Peritheciumlike bodies were numerous in the cultures, but no asci could be found. Transfers to flasks of corn meal made from one of the above tubes passed through the same course of development and produced peritheciumlike bodies. A few apparently immature asci were found in some of these, but though kept about two months no ascospores were ever seen. Other subcultures from this same series continued to produce conidia and the dark peritheciumlike bodies, but no mature asci were ever discovered. Chlamydospores of the usual kind were present in great abundance in some of the cultures.

Physalospora phormi Schröt. (72) as described from this host agrees with Glomerella and is presumably the perithecial form of the Gloeosporium from which our cultures were made. The conidia varied from 9 to 15 by 4.5 to 5 μ.

Gloeosporium phomiforme Sacc. and Ell. also described from this host is apparently a different organism, as the conidia are said to range from 5 to 6 by 3 to 3.5 μ. There seems little doubt that the species grown by the writers should be referred to *Glomerella cingulata* (Stonem.) S. and v. S., though no mature asci were seen.

PIMENTA ACRIS (SWARTZ) KOSTEL. (WILD CLOVE).

?Glomerella cingulata (Stonem.) S. and v. S.

On January 19 leaves with small dead areas were taken from a greenhouse plant, the surface sterilized as usual, and placed in a moist chamber. Acervuli of the usual character of Gloeosporium soon developed on the leaves, and later a few immature perithecia with asci were found, but the spores were not sufficiently developed for positive identification.

Cultures made from the conidia on these leaves produced a growth of the usual character. Conidia were formed, but no acervuli appeared until the cultures were nearly 3 weeks old. No setæ were found. Peritheciumlike bodies developed in the thickest sown plates, but no ascospores were seen. The conidia ranged from 11 to 17 by 4 to 6 μ. No fungus of this kind appears to have been reported on this host heretofore.

PIPER MACROPHYLLUM SWARTZ (PEPPERWORT).

?Glomerella cingulata (Stonem.) S. and v. S.

On January 30 apparently normal, healthy leaves taken from a greenhouse plant, after sterilization of the surfaces as usual, were placed in a moist chamber. The leaves soon became discolored, and on February 7 numerous acervuli were present. No perithecia were ever found on these leaves.

Slant agar tube cultures were made, using conidia from the leaves in moist chamber. The growth was of the usual appearance of Glomerella cultures, and scattered acervuli with pink masses of conidia appeared. On March 10 about 25 perithecia of different sizes had developed in one tube. These contained immature asci. Subcultures made from this tube showed the same characters as the first, except that numerous setæ were present in the acervuli. These cultures produced many perithecia, but no mature asci could be found. This seems to be the first report of the occurrence of such a fungus on this host.

PITCAIRNIA CORALLINA LINDEN.

Glomerella cingulata (Stonem.) S. and v. S.

On January 29 normal, apparently healthy leaves were taken from a greenhouse plant and after the usual treatment placed in a sterile moist chamber. The leaves soon became covered with dark blotches, and a few scattered acervuli developed. No setæ were found. On February 25 fertile perithecia of Glomerella were abundant on both sides of the leaf. No paraphyses were seen. The asci and spores were apparently identical with those from various other hosts. An ascus and ascospores are shown in Plate II, figures 25 and 25a.

Plate and tube cultures made from conidia on the leaves in moist chamber produced a growth of the usual appearance of Glomerella cultures. Acervuli soon appeared. Setæ were abundant in some of these cultures, whereas the original tubes showed no setæ. Chlamydospores also developed and in two corn-meal flasks peritheciumlike bodies occurred, but no asci were found. The conidia from the leaves in moist chamber varied from 12 to 18 by 5 to 6 μ; ascospores from the leaves measured 15 to 18 by 4.5 to 6 μ.

The host indexes mention no organism of this kind on this host.

PSIDIUM GUAJAVA L. (GUAVA).

Glomerella cingulata (Stonem.) S. and v. S.
Glomerella psidii (Del.) Sheldon.

Sheldon (78, 80) has already described the life history of this form. The work of the present writers covers the study of the development of the fungus on leaves in moist chamber and in pure cultures.

DEVELOPMENT ON LEAVES IN MOIST CHAMBER.

On January 29 five apparently healthy leaves were taken from a tree in the greenhouse and after the usual treatment placed in a sterile moist chamber. The leaves soon showed dark blotches and finally became entirely discolored. Acervuli developed first on the petiole and later occurred scattered over the upper and lower surfaces of the leaves. They appeared less numerous and more irregularly distributed than in the form produced on citrus leaves in moist chamber. On April 8 a few perithecia were found on these leaves.

On April 30 two small young leaves in whose axils no flower buds were located, also two leaves a year old in whose axils fruit had been borne, were treated as usual and placed in moist chamber. On May 16 acervuli were abundant on the old leaves, but none were present on the new leaves. Though kept until June 22 no acervuli or perithecia developed on the young leaves, while acervuli and perithecia were numerous on the older leaves. This would suggest the possibility of the fungus having entered the old leaves by way of the flowers of the previous season, while the flowers in the axils of the new leaves not having opened, the new leaves had not yet become infected.

One leaf, in the axil of which fruit had just set, did not develop any Gloeosporium in moist chamber nor did another which bore a flower in its axil.

Four terminal leaves from different shoots situated 1 to 4 inches beyond any fruit and four leaves at the base of fruits, were placed in moist chamber. One leaf in each set developed acervuli. These last experiments do not seem to indicate any clear connection between flowers and fruit and infected leaves in this case. It seems more probable that the dormant infections came from local infection of the leaves.

CULTURES.

Numerous cultures started from conidia from leaves placed in moist chamber at different times during the year, produced a mycelial growth of the usual general appearance of Glomerella. Acervuli were formed in all the cultures, but usually they were not numerous. The spore masses were pink. No setæ were found in any of the cultures. Chlamydospores occurred in some. Perithecia were never found in the cultures.

Cultures made from conidia from fruit of guava in the greenhouse had the same general appearance as those from leaves. Setæ appeared, frequently in great abundance, in nearly all the cultures derived from fruit. Chlamydospores were also abundant in some of these cultures, but no perithecia were found. The conidia from the host ranged from 13.5 to 19.5 by 4.5 to 6 μ. Conidia from cultures varied from 13.5 to 18 by 4.5 to 6 μ. Ascospores from the host ranged from 13.5 to 21 by 5.5 to 6 μ. An ascus and ascospores are shown in Plate I, figures 9 and 9a.

There is nothing, so far as could be determined, in the morphological characters or behavior of this fungus in cultures or on its host to distinguish it from *Glomerella cingulata* as it occurs on citrus fruits and other evergreen-leaved plants as well as pomaceous fruits. Inoculation experiments reported by Cobb (21) indicated that the fungus could be successfully inoculated into apple, banana, pear, and quince. The form on apple was also successfully transferred to guava by the same investigator.

RIBES OXYACANTHOIDES (GOOSEBERRY).

Glomerella cingulata (Stonem.) S. and v. S.
Gloeosporium ribicolum Ell. and Ev.

On July 5 decaying gooseberries were found at Arlington Farm, Va. Some of these berries showed acervuli of *Gloeosporium ribicolum* Ell. and Ev. and others developed acervuli when placed in a moist chamber.

Test tube cultures were made by transferring conidia from these berries. The growth in the tubes was of the usual appearance of Glomerella cultures. On July 14 acervuli were present in three of the four tubes. They were few in number and located about the point of inoculation. The development of the mycelium was rather more scanty than usual and showed little indication of the dark color which frequently develops in old cultures. These cultures never developed more acervuli, but small groups of perithecia appeared which were either sterile or immature. Transfers were made from each of these tubes to four others. These cultures developed very few acervuli and conidia. Two of these cultures developed distinct stromatic masses of perithecia, all fertile and producing typical ascospores. The massing of the perithecia in these two cultures was very conspicuous, as the perithecia of Glomerella are most frequently either scattered or but slightly aggregated.

Apples were inoculated with ascospores from these cultures, as described later, and the cultures made from the tissues of these decayed apples produced large quantities of perithecia but very few and minute acervuli. The conidia developed were mostly scattered. Plates poured from the cultures from the inoculated apple had a very characteristic appearance. The perithecia developed in great numbers and were quite evenly distributed throughout the medium instead of being aggregated in masses. Acervuli developed on the surface of the medium at certain points, but they were very small and inconspicuous. The perithecia appeared to be rather larger and thicker walled than usual in Glomerella, but the asci and spores as well as conidia agreed in all respects with those from other hosts. The passing of one generation of the fungus through the apple had apparently increased its vitality in some way, as it grew much more luxuriantly in the cultures made from the apple and developed perithecia and conidia much more abundantly.

RUBUS OCCIDENTALIS L. (BLACK RASPBERRY).

Glomerella cingulata (Stonem.) S. and v. S.
Glomerella rubicola (Stonem.) S. and v. S.
Gloeosporium rubi E. and E.

Diseased canes of black raspberry received from Shelbyville, Tenn., were placed in a moist chamber. The diseased areas soon produced typical acervuli with dark-colored setæ. Later many perithecia of Glomerella also appeared on the canes.

On March 29 the surface of some of the diseased canes was disinfected as usual, and pieces of the discolored inner bark and wood were transferred to flasks of sterile corn meal. These cultures produced a growth of white mycelium but no acervuli. On April 17 perithecia of Glomerella were present with mature asci and ascospores apparently identical with those found on the canes in the moist chamber.

Other cultures made from conidia on the same canes in the moist chamber produced conidia but no distinct acervuli. Fertile perithecia developed in large numbers over the entire surface of these cultures. Other cultures from the same source and also subcultures continued to produce fertile perithecia in abundance, but conidia were always few and no distinct acervuli were found. Subcultures made from ascospores also produced an abundance of fertile perithecia, but no conidia were found. Chlamydospores also occurred in these cultures. The conidia found ranged from 10.5 to 18 by 5 to 6.5 μ. Ascospores averaged about 15 by 6 μ.

The perithecial stage of this form was first produced in culture by Stoneman (89). Several species of Physalospora and of Laestadia have been described from Rubus which do not differ essentially from this Glomerella, so far as the descriptions go. There seems to be no way of separating this fungus from *Glomerella cingulata*. In the absence of inoculation experiments showing that it will not pass to the apple or other hosts it is referred to that species.

RUBUS TRIVIALIS MICHX. (WHITE DEWBERRY).

Gloeosporium rufomaculans (Berk.) Thüm.
Gloeosporium rubi E. and E.

Early in May, 1909, specimens of white dewberries were received from Macon, Ga. The fruit was soft and had a water-soaked appearance, suggesting a fungous disease. After washing the berries thoroughly in corrosive sublimate, cultures were made on corn meal by transferring portions of the pulp from the berries. One of the flasks to which pulp was transferred, developed a pure growth of Gloeosporium of the usual appearance. The acervuli were numerous and produced pinkish masses of conidia. No perithecia developed in these cultures. Other specimens of the same diseased dewberries kept in moist chamber also produced acervuli. Poured plates were made with conidia from these acervuli. Acervuli but no setæ were found in the cultures, and no perithecia were produced. The conidia varied in size from 9 to 16 by 4.5 to 6 μ. In one set of these cultures the conidia averaged rather smaller than in the others, being mostly 9 to 13.5 by 4.5 μ. This form does not appear to be distinct from that just described from the black raspberry, though the material used in these cultures produced no perithecia. Inoculation experiments described later show that this form adapts itself quickly to the apple.

SMILAX MEDICA SCHL. AND CHAM.

Gloeosporium rufomaculans (Berk.) Thüm.

On October 31 acervuli of a Gloeosporium were found on leaves of this Smilax in the greenhouse of the Department of Agriculture. Plates which were poured from this material produced a growth of mycelium of the usual character and an abundance of conidia but no distinct acervuli. Transfers were made from these plates to tubes which soon produced large acervuli with pinkish masses of conidia. Later, the mycelium became dark colored, but no perithecia were ever found and no setæ were seen. The conidia ranged from 10.5 to 19.5 by 5 to 6 μ. The fungus as it appeared on the host and in cultures showed no characters to distinguish it from the conidial forms of Glomerella found on most of the other hosts studied. No species of Gloeosporium or Glomerella seems to have been reported heretofore on Smilax.

THEA JAPONICA (L.) BAILL. (CAMELLIA).

Glomerella cingulata (Stonem.) S. and v. S.
Colletotrichum camelliae Mass.

DEVELOPMENT ON LEAVES IN MOIST CHAMBER.

On January 29 apparently normal, healthy leaves were taken from a greenhouse plant, the surfaces sterilized as usual, and the leaves placed in a sterile moist chamber. They soon began to show a dark discoloration extending from the petiole up the midrib almost to the tip and finally became entirely discolored. Acervuli occurred on all the leaves, and fertile perithecia of Glomerella were also present but not abundant.

CULTURES.

Tube cultures were made, using conidia from the acervuli on the leaves in moist chamber, as described above. These cultures produced abundant acervuli but no perithecia. No setæ occurred, though setæ were abundant in the acervuli on the leaf. In other cultures from the same leaves acervuli and chlamydospores were found, but no perithecia.

In February leaves of camellia, showing acervuli of Gloeosporium, were received from South Carolina. Cultures were made from the conidia on these leaves. The fungus developed in the usual manner, but produced very few conidia and no distinct acervuli. The mycelium later became dark colored, and finally two perithecial forms were found; one appeared to be Glomerella, while the other produced large brown septate ascospores, indicating that the culture was impure. The Glomerella, however, was apparently identical with that on the leaves and presumably originated from the conidia used. The conidia on the host ranged from 13.5 to 18 by 4.5 to 6 μ. Setæ were rarely found. The ascospores from perithecia on different leaves varied greatly. On one leaf they ranged from 10.5 to 18 by 6 μ and were only slightly curved or inequilateral. On another leaf they were more distinctly curved and ranged from 15 to 28.5 by 4.5 to 9 μ. (See Pl. I, figs. 15 and 15a.) Though the ascospores in this case appear to show a greater range of variation than in some other cases, still there appears to be no good basis for separating this form from that on the orange.

THEA SINENSIS L. (TEA).

Glomerella cingulata (Stonem.) S. and v. S.
Laestadia camelliae (Cke.) Berl. and Vogl.
Colletotrichum camelliae Mass.

DEVELOPMENT ON LEAVES IN MOIST CHAMBER.

On December 4 leaves with small dead areas were taken from tea plants in the greenhouse and placed in a sterile moist chamber. Acervuli with setæ and perithecia of Glomerella soon appeared on the leaves and many mature asci were found. No paraphyses were seen. An ascus and ascospores are shown in Plate II, figures 16 and 16a.

On April 29 other leaves showing small discolored areas were placed in moist chamber. Acervuli of Glomerella with pink masses of conidia soon appeared on these, and 10 days later an abundance of mature perithecia were found. These perithecia in most cases showed rather distinct but inconspicuous beaks. Paraphyses were also found in these.

Attempts made in February and May to obtain the fungus from apparently healthy tea leaves placed in moist chamber were unsuccessful.

CULTURES.

Two cultures on sterile corn meal, made by transfer of conidia from a tea leaf in a moist chamber, produced a few conidia but no distinct acervuli. Mature perithecia of Glomerella were found in both these cultures in about three weeks. Chlamydospores were also present.

On July 5 a tube culture was started from a single conidium. This developed the usual growth and produced acervuli. Two subcultures were made in flasks of corn meal. These cultures started about as usual and were identical in appearance, but the mycelium began to assume a bluish smoky color rather sooner than in most cases. Acervuli with pinkish masses of conidia also developed. These cultures were kept for nearly a year, but no perithecia were ever found. The conidia on the leaves in moist chamber ranged from 15 to 21 by 4.5 to 6.5 μ.

Several species of Gloeosporium and Colletotrichum have been described as occurring on tea. They all appear to belong to this Glomerella except *Gloeosporium theae-sinensis* Miyake which has conidia only 4 to 6 by 2 μ. The conidial form might be referred either to Gloeosporium or Colletotrichum, as setæ were found on leaves in moist chamber but not in cultures. A microscopic study of the type specimen of Massee's (58) species, *Colletotrichum camelliae*, leaves no doubt of its identity with the conidial form of the fungus just described.

THEOBROMA CACAO L. (CHOCOLATE NUT).

Glomerella cingulata (Stonem.) S. and v. S.
Colletotrichum theobromicolum Delacr.

On January 19 leaves of cacao or chocolate nut showing small dead areas but no fungus fructifications were taken from greenhouse plants, the surfaces sterilized as usual, and placed in a moist chamber. Many acervuli of Colletotrichum soon appeared, especially along the midrib. Setæ were abundant and also immature perithecia, which later (March 10) showed an abundance of mature asci and ascospores. Paraphyses were also seen. An ascus and ascopores are shown in Plate II, figures 24 and 24a.

Plate cultures were made, using conidia from the leaves in moist chamber just described. Transfers were made from these plates to four tubes in which a growth of whitish mycelium of the usual character developed and soon large acervuli with pinkish masses of conidia appeared at the point of planting in two of the tubes. In the other two no distinct acervuli were found. Setæ were more frequently present on the host than in the cultures. In some of the poured plates no setæ were found. In one tube where setæ were abundant one was found bearing a spore, as sometimes happens in the species occurring on cotton. No perithecia were ever found in any of these pure cultures, and no ascogenous fungus has been described from this host, so far as noted, which seems to agree with the

Glomerella which appeared on the leaves. The conidia from the leaves ranged from 15 to 18 by 6 μ and agreed in all respects with *Colletotrichum theobromicolum* Delacr. (26). Two or three other species of Colletotrichum have been described from this host. The conidial measurements given are smaller than those of our organism, and they may perhaps belong to different species. Bancroft (5) has discussed the species on this host.

VANILLA PLANIFOLIA ANDREWS (VANILLA).

Gloeosporium rufomaculans (Berk.) Thüm.

On January 26 plates were poured, using conidia from acervuli on leaves of vanilla received from Miami, Fla. Setæ were present in some of the acervuli and wanting in others. Acervuli soon developed in the poured plates, and four subcultures were made in tubes. Acervuli soon developed in the tubes, but their number, size, and distribution varied greatly. In one tube there was only one large acervulus, in another the surface of the medium was thickly dotted with acervuli with pinkish spore masses. In some of the tubes the mycelium remained whitish, in others it became quite dark colored. The variations in amount and color of the mycelium, and in the number, size, and distribution of the acervuli were very striking. No perithecia or peritheciumlike bodies were found in any of these cultures. The conidia from the leaves ranged from 13.5 to 24 by 4.5 to 6 μ.

There are no sufficient morphological characters to distinguish this fungus from that found on the grape and apple. It has therefore been referred to the same species. *Physalospora vanillae* A. Zimm. (97) is apparently the perithecial form.

VITIS LABRUSCA L. (CONCORD GRAPE).

Glomerella cingulata (Stonem.) S. and v. S.
Gloeosporium rufomaculans (Berk.) Thüm.

On July 30 plates were poured from acervuli of Gloeosporium found on rotten grapes at Washington, D. C. These produced the usual whitish mycelium and numerous acervuli, and a little later perithecia of Glomerella with mature asci and spores were found. Transfers of perithecia from these plates to tubes produced large acervuli and a considerable growth of the dark bluish hyphæ which frequently characterize old cultures. Mature asci and perithecia were found in one of these tubes. In two others perithecia were present but no asci were seen.

On September 25 four plates were poured, using conidia from a single acervulus in the tube just described, which contained the fertile perithecia. Transfers were made from these plates to four other tubes. Acervuli developed in abundance in tubes *a* and *b*. The mycelium was white and rather scanty. In tubes *c* and *d* the mycelium was much more abundant and darker colored. Chlamydospores were also found in these cultures. On October 16 many perithecia were present in tube *a* but none in *b*. The difference between these two tubes was striking, though the cultures came originally from the same acervulus. Variations in the size and shape of the asci are shown in Plate III, figures 30 to 34.

In two cultures out of eight made in August from diseased tissue on small black sunken spots on shoots of a Concord grapevine from Vienna, Va., both acervuli and perithecia of Glomerella were produced. Setæ were found in these acervuli. As other organisms predominated in most of the cultures, it is, of course, uncertain whether any of these cankers were primarily due to Glomerella, which has not heretofore been reported as occurring upon grape shoots, so far as known. Setæ seemed to occur less frequently in the form from the grape and apple than in those from other hosts. Other cultures from grapes from different parts of Virginia produced an abundance of acervuli, and also in one case numerous peritheciumlike or sclerotoid bodies, which always remained sterile. The asci ranged from 55 to 98.5 by 9 to 15 μ. Asci and ascospores are shown in Plate I, figures 1, 1a, 2, and 2a.

The perithecial form seems to be the *Physalospora baccae* of Cavara (17). The conidial form has been described by the same author as *Gloeosporium physalosporae*.

MISCELLANEOUS.

In order to compare the behavior of Glomerella from different hosts in pure cultures, tubes were inoculated February 7 with conidia from leaves of the following six hosts which were growing in the greenhouse: Caryota, Costus, Curculigo, Maranta, Persea, and Piper. These cultures all made a growth practically identical in appearance, and most of the tubes produced acervuli varying more or less in number and size. The mycelial growth was about equal in all. One tube from Costus and one from Curculigo failed to produce acervuli. The difference in these cultures from different hosts was much less marked than is frequently the case in cultures made from a single acervulus on the same host.

On January 29 apparently healthy leaves were taken from nine different hosts in the greenhouse, as follows: *Citrus limonum*, *Citrus decumana*, *Citrus nobilis*, *Eriobotrya japonica*, *Psidium guajava*, *Thea japonica*, *Pitcairnia corallina*, and *Ficus longifolia*. The surfaces were thoroughly washed with corrosive sublimate, 1 to 500, and the leaves then placed in sterile moist chambers. On February 15 all the leaves had developed acervuli of Glomerella and some showed perithecia as well.

From these and numerous other experiments of a similar kind performed at different times during the year with leaves from other plants, it appears that this fungus is quite generally present in the leaves of many plants in a dormant or innocuous condition awaiting some weakening of the host or other favorable condition which may give it an opportunity to develop.

PEDIGREED CULTURES OF GLOMERELLA CINGULATA FROM AVOCADO.

The characters compared in the pure-line cultures were chiefly the relative abundance and particular characteristics of the conidial and perithecial fructifications. These were all perithecium-producing strains at the start. In some cultures conidia predominated and but few perithecia occurred; in others conidia were few and perithecia predominated. In some the conidia were scattered and hyphomycetous, while in others they were produced in distinct acervuli, frequently large. The perithecia were sometimes separate and scattered evenly and thickly over the surface of the medium; in other instances they were aggregated in dense masses.

The arrangement of the perithecia, whether separate or aggregated in a stroma, has usually been regarded by mycologists as important and has been used as the basis for separating genera and families. All the cultures were grown on the same medium (corn-meal agar) in a culture room under ordinary room temperature and conditions.

FIRST SERIES OF SEVEN GENERATIONS STARTED FROM A SINGLE ASCOSPORE.

Generations 1 and 2 were very similar in appearance. They produced conidia and an abundance of perithecia evenly scattered over the surface of the medium, as shown in tube 2*a*, Plate VIII. Generation 1 also showed some submerged perithecia.

The third generation was very similar to the first two but showed more of the deeply submerged perithecia.

In the fourth generation the perithecia, instead of being scattered evenly over the surface, as in the three previous generations, were compacted in black masses, giving the cultures a very different appearance from the earlier generations.

Generations 5, 6, and 7 showed the same characters as generation 4. The variation in arrangement and grouping of the perithecia seems to have been transmitted from generation 4 through these three generations. This series was discontinued at this point. In this case an important variation or mutation suddenly occurred in the fourth generation and was transmitted through three following generations.

CONIDIAL GENERATIONS FROM THE SAME HOST.

Generation 1 was started from a single conidium taken from a culture which also produced fertile perithecia. Acervuli and conidia were abundant at first in these cultures and a few perithecia formed in the lower part of the tubes.

Generations 2, 3, and 4 varied but slightly in general appearance and relative abundance of acervuli and perithecia from generation 1.

Generation 5 was practically the same as generation 4.

Generations 6 and 7, consisting of three tubes each, showed acervuli in abundance and lines of submerged perithecia developed in the medium as in some of the ascospore cultures, but they were much fewer.

Generation 8 showed an apparent reversion to the condition of the first five generations, with the same general distribution, arrangement, and relative number of acervuli and perithecia.

Generation 9 was strikingly different from generation 8. Acervuli were few and the perithecia very numerous and thickly scattered over the surface of the medium, resembling most of the ascospore generations. Tube 9*a* is shown in Plate IX. Two plates poured from this tube showing the same predominance of perithecia are illustrated in Plate XIV.

Generation 10 showed an apparent reversion again to the form in the first five generations. Acervuli were abundant and large; the perithecia were fewer and mostly grouped about the acervuli.

Generation 11, tube *b*, was practically identical in appearance with generation 10, tube *b*. Acervuli and perithecia were numerous. Generation 11, tube *c*, was very strikingly different from generation 10, tube *c*, showing large acervuli and masses of conidia, but very few perithecia.

Generation 12, consisting of tubes *b* and *c*, did not show the characters of the previous generation but rather the reverse, perithecia being abundant and acervuli few.

Generation 13 produced abundant acervuli, but the perithecia were much fewer than in generation 12. The two tubes *b* and *c* are shown in Plate VIII.

Tubes *b* and *c* of generation 14, derived from generation 13, tubes *b* and *c*, respectively, were strikingly different. Tube *b* produced almost entirely conidia with scattered acervuli, while *c* consisted almost entirely of perithecia formed along the line of inoculation. These tubes are shown in Plate VIII.

Tubes *b* and *c*, generation 15, were very similar to tubes *b* of generations 13 and 14. A few perithecia were present in each, but they were not numerous and predominating, as in tube *c* of generation 14.

Of generation 16, tubes *b* and *c* scarcely differed from 15. Acervuli and perithecia were present in both. They are shown in Plate IX. Seven subcultures from tube 16 *b* showed rather regular intergradations from tube 1, which contained perithecia chiefly, to tube 7, which contained chiefly acervuli. These subcultures are shown in Plate X.

Tubes *b* and *c* of generation 17 were strikingly and remarkably different. Tube *b* produced perithecia in abundance, covering the surface of the medium as in most ascospore generations. A very few small acervuli were present. Tube *c* showed an abundance of large acervuli and a very few scattered perithecia. These two cultures are shown in Plate IX together with their parent cultures 16 *b* and 16 *c*.

Of 4 subcultures of conidia, numbered 17 *d*, *e*, *f*, and *g*, from culture 16 *b*, three showed perithecia predominating like 17 *b*, and one had acervuli predominating as in the original 16 *b*. (See Pl. XII.) Eight more subcultures made from tube 16 *b* gave four with perithecia like tube 17 *b* and four of an intermediate character, acervuli and perithecia both being present. Six other subcultures from tube 16 *b* resembled the parent culture. None of them showed a continuous layer of perithecia as in tube 17 *b*. Nine subcultures made from conidia from tube 16 *c* were all very similar in appearance throughout their growth. Acervuli were first produced as in the parent tube, but an abundance of perithecia later appeared. They were aggregated in masses in marked contrast to those in cultures from tube 16 *b*. Seven of these tubes are shown in Plate XIII. Out of 8 transfers from culture 17 *b*, which, as mentioned above, produced perithecia covering almost the entire surface of the medium, 7 were almost identical in appearance, showing a great predominance of acervuli and few perithecia, while only one resembled the parent culture. Tube 17 *b* with 6 of these subcultures is shown in Plate XI.

Tubes *b* and *c* of generation 18 grown from tubes 17 *b* and *c*, respectively, were very different in appearance. Acervuli predominated in culture *b* and perithecia in culture *c*, just the opposite of the parent cultures.

Tubes *b* and *c* of generation 19 were about like the ordinary conidial cultures. Acervuli and perithecia were both present, but acervuli predominated. Tube 19 *b* is shown in Plate XII.

Generation 20 *b*, from tube 19 *b*, produced both conidia and perithecia, but the latter were more abundant and covered a broad area on both sides of the culture, as illustrated in Plate XII.

Generations 21, 22, and 23 were all very much like the ordinary conidial cultures in which acervuli predominated and were most conspicuous, although some perithecia were always produced.

These variations might perhaps be regarded as renewed expression of latent hereditary characters or as mutations. If mutations, we should rather expect them to be transmitted more or less regularly, but they appear for one or a few generations and then disappear without any particular regularity or definite sequence. This behavior would appear to put them in the category of fluctuating variations, which are not supposed to be transmitted. The media and the conditions under which the cultures were grown were made as uniform as practicable in order to eliminate the influence of different factors of environment.

OCCURRENCE OF SETÆ AND PERITHECIA IN GLOMERELLA.

TABLE I.—*Record of the writers' observations on the occurrence of setæ and perithecia in Glomerella.*

Host.	Setæ.		Perithecia.		Miscellaneous.
	Cultures.	Host.	Cultures.	Host.	
Annona cherimola (cherimoya).	Present	Not observed			
Brya ebenus (ebony)		do		Present	
Caryota rumphiana		Sometimes present.		do	
Cinnamomum zeylanicum (cinnamon).		Not observed	Present		
Citrullus vulgaris (watermelon).	Abundant	do			
Citrus aurantium sinensis (sweet orange).	Sometimes present.	Sometimes present.		Present	
Citrus decumana (pomelo)	do	do	Present	do	
Citrus limonum (lemon)	do	do		do	
Citrus nobilis (mandarin)	Few seen, sometimes absent.	Present; not numerous.		do	
Coffea arabica (coffee)		Sometimes present.		do	
Costus speciosus (spiral flag).	Sometimes present.	Present; not numerous.		do	
Crataegus sp. (hawthorn)					
Cucumis sativus (cucumber).	Sometimes present.				No pure cultures.
Cucurbita pepo (squash)		Sometimes present.			
Curculigo		do		Present	
Eriobotrya japonica (loquat).		do		do	
Ficus carica (fig)	Sometimes present.		Present		Paraphyses present.
Ficus elastica (rubber plant).	do		do	Present	
Ficus longifolia		Sometimes present.		do	
Ginkgo biloba			Present		
Gleditsia triacanthos (honey locust).			do		
Gossypium hirsutum (cotton).	Usually present.	Usually present.	do		
Hedyscepe (palm)				Present	No cultures.
Ligustrum vulgare (privet)	Sometimes present.	Present; not numerous.	Present	do	
Malus sylvestris (apple)		Sometimes present.	do	do	(1)
Mangifera sp. (mango)	Sometimes present.			Present; asci immature.	
Maranta arundinacea				Present but immature.	
Musa paradisiaca sapientum (banana).					
Oxycoccus macrocarpus (cranberry).	Present		Present		
Persea gratissima (avocado)	Sometimes present.	Present on fruit.	do	Present	
Phaseolus vulgaris (wax bean).	do	Present	do		

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[1] A few brown ascospores in culture; chromogenic form found.

TABLE I.—*Record of the writers' observations on the occurrence of setæ and perithecia in Glomerella*—Continued.

Host.	Setæ.		Perithecia.		Miscellaneous.
	Cultures.	Host.	Cultures.	Host.	
Phormium tenax	Found only on cabbage leaf inoculated with this form.		Present; asci immature.		
Pimenta acris (wild clove)			Present but sterile.	Present but immature.	
Piper macrophylla (pepperwort).	Sometimes present.		Present; asci immature.		
Pitcairnia corallina	do			Present	
Psidium guajava (guava)	Present; not numerous.	Abundant on fruit; rare on leaves.		Present on leaves.	
Ribes oxyacanthoides (gooseberry).			Present		
Rubus occidentalis (black raspberry).		Sometimes present.	do	Present	
Rubus trivialis (white dewberry).					
Smilax medica					
Thea japonica (camellia)		Sometimes present.	Doubtful; culture not pure.	Present	
Thea sinensis (tea)		do	Present	do	(1)
Theobroma cacao (chocolate nut).	Sometimes present.	do		Paraphyses present.	(2)
Vanilla planifolia (vanilla)		do			
Vitis labrusca (Concord grape).	Sometimes present.		Present		

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(1) Paraphyses present on leaves.

(2) In one case a small spore was found attached to a seta.

TABLE II.—*Hosts from which ascogenous perithecia of Glomerella as well as conidia have been reported either in cultures or on the host, or both.*

Host.	Perithecia.		Paraphyses.	Investigators.
	Cultures.	Host.		
Anthurium warocqueanum		Present		Edgerton, 1908.
Artocarpus incisa		do		Delacroix, 1905.
Asclepias syriaca (milkweed)		do		Edgerton, 1908.
Brya ebeneus (Jamaica ebony).		do		Shear and Wood.
Capsicum annum (pepper)	Present			Stoneman, 1898.
Caryota rumphiana		Present		Shear and Wood, 1909.
Cattleya sp		do	Present	Maublanc and Lasnier, 1904.
Cinnamomum zeylanicum (cinnamon).	Present			Shear and Wood, 1909.
Citrus aurantium (sweet orange).		Present		Do.
Citrus decumana (pomelo)	Present	do		Do.
Citrus limonum (lemon)		do		Do.
Citrus nobilis (mandarin)		do		Shear and Wood.
Coelogyne cristata (orchid)		do		Edgerton, 1909.
Coffea arabica (coffee)	Present	Present on leaves.		Edgerton, 1908.
Do		do		Shear and Wood, 1909.
Costus speciosus (spiral flag)		do		Do.
Curculigo sp		Present		Do.
Cydonia vulgaris (quince)	Present	Present on leaves.		Edgerton, 1909.
Dracaena	do	do	Present	Sheldon, 1907.
Do	do	do	do	Edgerton, 1908.
Eriobotrya japonica (loquat)		Present		Shear and Wood, 1909.
Ficus carica (fig)		Present on fruit.		Edgerton, 1909.
Do	Present	do		Edgerton, 1911.
Do	do			Shear and Wood.
Ficus elastica (rubber plant)	do	Present on leaves.		Shear and Wood, April, 1907.
Do	do	do		Koorders, November, 1907.
Do	do	do		Edgerton, 1908.

TABLE II.—*Hosts from which ascogenous perithecia of Glomerella as well as conidi have been reported either in cultures or on the host, or both*—Continued.

Host.	Perithecia.		Paraphyses.	Investigators.
	Cultures.	Host.		
Ficus longifolia		Present		Shear and Wood, 1909.
Ginkgo biloba	Present			Shear and Wood, 1907.
Gleditsia triacanthos (honey locust).	do			Do.
Gossypium hirsutum (cotton)	do			Do.
Do	do			Edgerton, 1908.
Do		Present on bolls.	Present	Edgerton, 1909.
Hedyscepe sp. (palm)		Present		Shear and Wood, 1909.
Ligustrum vulgare (privet)	Present	do		Stoneman, 1898.
Do	do	do		Shear and Wood, 1909.
Malus sylvestris (apple)	do	On fruit		Clinton, 1902.
Do	do	On fruit and cankers.		Von Schrenk and Spaulding, 1903.
Do	do	On fruit		Scott, 1906.
Do	do	do		Shear and Wood, 1907.
Do	do	do		Edgerton, 1908.
Mangifera sp. (mango)		Present		Shear and Wood.
Maranta arundinacea		do		Shear and Wood, 1909.
Maxillaria picta (orchid)	Present	Present on leaves.		Stoneman, 1898.
Orchid		Present		Edgerton, 1908.
Oxycoccus macrocarpus (cranberry).	Present			Shear and Wood, 1907.
Persea gratissima (avocado)	do	Present		Shear and Wood, 1909.
Phaseolus vulgaris (wax bean).	do			Shear and Wood, 1907.
Phormium tenax	do			Shear and Wood, 1909.
Pimenta acris (wild clove)	Present; sterile.	Present		Shear and Wood.
Piper macrophylla (pepperwort).	Present			Shear and Wood, 1907.
Pitcairnia corallina		Present		Shear and Wood, 1909.
Psidium guajava (guava)	Present		Present	Sheldon, 1905.
Do		Present		Shear and Wood, 1909.
Ribes oxyacanthoides (gooseberry).	Present			Shear and Wood.
Rubus occidentalis (black raspberry).	do	Present		Shear and Wood, 1909.
Rubus strigosus (red raspberry).	do			Stoneman, 1898.
Sarracenia purpurea (pitcher plant).		Present on leaves.		Edgerton, 1908.
Thea japonica (camellia)	Doubtful	Present		Shear and Wood, 1909.
Thea sinensis (tea)	Present	do		Do.
Theobroma cacao (chocolate nut).		do		Shear and Wood.
Vanilla sp. (vanilla)		do		Stoneman, 1898.
Vitis labrusca (Concord grape)	Present			Shear, 1907.

VARIABILITY OF GLOMERELLA.

The extreme variability of races of Glomerella from the same host which is in some cases greater than that of forms from different hosts renders it exceedingly difficult to make a satisfactory classification of the forms. No character, either morphological or physiological, seems to be well fixed. The appearance of the mycelium in cultures on agar is usually rather uniform. The hyphæ are mostly submerged and white at first, forming a circular colony. After a short time the mycelium frequently becomes dark greenish or smoke colored, and occasionally a pink color develops, as was the case in the chromogenic form obtained from the apple (p. 39). The dark color of the cultures is sometimes due to colored hyphæ and at other times to the presence of the black perithecia or sclerotia and appressoria.

CONIDIA.

The conidia show exceeding variability in their manner of production and all their morphological characters. In some cultures they are borne separately on scattered sporophores, suggesting a very diffuse hyphomycete. All intergradations between this form and forms having very large, compact, and distinct acervuli occur. In one strain derived from the gooseberry, certain cultures produced an aerial growth and conidiophores more or less erect and clustered, suggesting in macroscopic appearance a Verticillium. Pure cultures from these conidia, however, produced the usual form with acervuli, which was followed by the development of perithecia and ascospores. In size, shape, and color the conidia are also very variable. They have been found to range from 10 to 42 by 3 to 9 μ from the same host. They are rarely or never distinctly curved. When scattered on a slide they usually appear colorless, but vary from a very pale-cream to a bright-salmon color in masses. Occasionally a few dark-colored conidia have been found.

SETÆ.

Setæ are frequently entirely wanting in some cultures while abundant in others from the same host. Some acervuli from one single-spore culture may show many setæ, others few, and still others none. The setæ also vary greatly in size, length, and septation. In two forms, those from cotton and Theobroma, they have been found bearing conidia.

APPRESSORIA, OR CHLAMYDOSPORES.

The appressoria, or chlamydospores, are also exceedingly variable in size and shape. As has been pointed out by Hasselbring (45) and others, their occurrence appears to bear some relation to lack of available nutriment and to contact with some hard surface.

In water drop cultures on glass slides they usually develop either from conidia or ascospores in 24 to 48 hours. (See figs. 2 and 3.)

A germinating chlamydospore is shown in figure 4.

YEAST AND OTHER FORMS.

Viala and Pacottet (92) have reported the occurrence of yeast forms of Gloeosporium. Yeast forms have never occurred in any of the writers' pure cultures. They have occasionally been found, but only in cultures made directly from fruit, in which cases they were evidently contaminations. The same authors also report the production of spermagonia and pycnidia in *Colletotrichum lindemuthianum.* No fructifications of this kind have ever been found by the writers in pure cultures of Glomerella. The writers have never seen the endospores described by Sheldon (79) and confirmed by Taubenhaus (91).

PERITHECIA.

Perithecia have been found to vary in abundance, size, shape, arrangement, and location with reference to the surface of the medium. They are generally globose or subglobose, though sometimes elongated or pear shaped. The beak when present is usually very short, though commonly the perithecia are merely papillate. In rare cases, however, they have been found with distinct elongated beaks similar to those illustrated by Stoneman (89). On the host plant they have always been found embedded in the tissues. In artificial cultures they are usually embedded but occasionally form erumpent, superficial masses. Sometimes they are evenly scattered and entirely separate, as shown in Plate XV; at other times they are aggregated and seated upon a more or less distinct stromatic base. Occasionally they are almost sterile or are represented by simple black, solid, sclerotoid bodies.

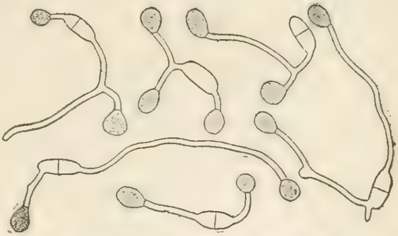

FIG. 2.—Germinating conidia of *Glomerella cingulata* from a culture from pear, showing the formation of chlamydospores after 24 hours in drop cultures of sterile water.

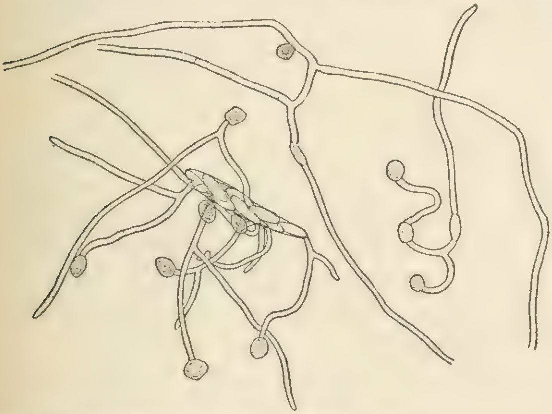

FIG. 3.—Germinating ascospores of *Glomerella cingulata* from cultures from gooseberry, showing formation of chlamydospores after 55 hours in drop cultures of sterile water. Ascospores usually produce longer germ tubes than conidia.

ASCI.

The asci are also extremely variable in size and shape, as will be observed by a comparison of Plates I, II, and III and the measurements of specimens from the same and different hosts, as recorded in Table III. The apex of the ascus shows a peculiar structure which apparently has some relation to the expulsion of the spores. This feature has been discussed by Koorders (54).

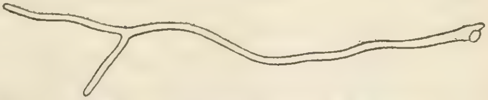

FIG. 4.—A germinating chlamydospore, or appressorium, of *Glomerella cingulata* from a culture from gooseberry, showing the development of the germ tube after 24 hours in corn-meal agar.

ASCOSPORES.

The ascospores show almost as great variation in size, shape, and other characteristics as do the conidia. They range from 9 to 24 by 3 to 7.5 μ. The contents are sometimes rather coarse and granular, at other times more homogeneous. Vacuoles or oil drops are frequently present, sometimes one large one in the center or at each end, at other times two smaller ones at each end. Ascospores are almost always slightly curved. They are usually almost colorless, but when old and in mass they frequently show a pale-lemon or salmon color, and occasionally very old spores are decidedly dark colored.

PARAPHYSES.

The early investigators of Glomerella do not mention the presence of paraphyses. It will be seen by consulting Table II that these bodies have not been very frequently found in our material or reported by others. When observed they appear to be very thin walled and are not always easily discerned. Their presence or absence does not seem to be sufficiently constant to be of much taxonomic value.

HOST RELATIONS.

Most of the forms from various hosts appear to be able to infect other hosts under certain conditions, at least, as indicated in Table IV, which gives the results of cross-inoculation experiments of other authors as well as of the writers. With a few exceptions, such as the bean and cotton anthracnose and perhaps the form from the squash, different races from the same host seem to vary as greatly in virility as do forms from different hosts.

CAUSES OF VARIATIONS.

In dealing with the phenomena of heredity and variation in Glomerella there is apparently no reason to believe that the Mendelian theory is involved or that heterozygosis takes place, as no union of nuclei between different individuals or species is known to occur. Edgerton (32) has recently expressed his belief in a cross-fertilization between two strains of Glomerella from Populus, but the evidence given is not conclusive.

It seems clear that whatever fusions may occur between nuclei in the development of the individual organism which arises from a single spore, such fusions, though they be admitted to represent sexual union, could scarcely be conceived to add or transmit any new characters to the resulting progeny unless they were characters acquired by one of the fusing nuclei and not by the other during the life history of the individual. It is difficult to conceive how the union of two closely related nuclei originating in the same individual or the same cell could add to the essential characters of the organism in any way.

Individuals originating from single spores of Glomerella must be regarded as homozygous so far as it is possible to ascertain at present, i. e., no union of nuclei or gametes between different individuals, races, or strains has been proved.

Whatever differences the progeny of such individuals might show would evidently be due to mutation or some other internal cause, such as the renewed expression of latent hereditary characters, or else to some external or environmental action.

As it has been impossible to trace any causal relation or connection between most of the phenomena of variation observed and the conditions of environment to which the organisms were subjected, it must be concluded that the inducing causes are internal or else so obscure as to escape observation. In any case the evidence accumulated by others as well as by the writers appears sufficient to justify the conclusion that many of the variations observed and reported here are not entirely due to any effect of simple environmental factors. It must be remembered, however, that it is difficult if not impossible at present to standardize media and methods with sufficient accuracy to positively determine the exact effect of environmental factors on these fungi. Gorham (38) and others have pointed out the apparent impossibility of standardizing media containing agar and other organic compounds. Synthetic media of pure inorganic chemicals can not be substituted for many fungi, as they do not usually fruit on such media. More work is needed to verify the conclusions of Stevens and Hall (87) and others in regard to the direct effect of modifications of the chemical constituents of culture media on the behavior of parasitic fungi. The problem is evidently far more complex than some investigators have appreciated, and its complete solution can scarcely be hoped for in the near future, but the most hopeful line of attack seems to be that of pedigreed cultures of asexual or unisexual organisms grown and observed under the most exactly determined and controlled conditions possible and in sufficiently large numbers and through enough generations to reduce probable errors from accidental causes to a minimum.

The work of Jennings (49) with Paramecium and that of Barber (6), Will (96), Beijerinck (11), and Hansen (44) on yeasts, as well as that of other authors cited by Pringsheim (65), demonstrate at least one thing, and that is the actual existence of rather distinct races or strains within species. These races possess more or less distinctive and constant morphological or physiological characteristics which are generally inherited by their progeny and are apparently not primarily dependent upon environmental conditions.

TABLE III.—*Measurements of conidia and ascospores from cultures and from the hosts, showing the ordinary range of variation.*

Host.	Conidia.		Ascospores.	
	Cultures.	Host.	Cultures.	Host.
	μ	μ	μ	μ
Annona cherimola (cherimoya).	12–16.5 by 4–4.5	12–19.5 by 4–4.5		
Brya ebenus		12–19.5 by 4.5–5		12–18 by 4.5–6.
Caryota rumphiana		13.5–25 by 4.5–6		16.5–21 by 6.
Cinnamomum zeylanicum (cinnamon).	10.5–12 by 3–4	12–21 by 5–6		
Citrullus vulgaris (watermelon).	9–12 by 4.5–5			
Citrus aurantium sinensis (sweet orange).	10.5–18 by 3–4.5	12–18 by 4.5–7.5		12–18 by 4.5–6.
Citrus decumana (pomelo)	14–17 by 4.5–7.5	15–18 by 4.5–5		18–23 by 4.5–6.
Citrus limonum (lemon)	10.5–18 by 4–5	13–18 by 4.5–6		13.5–19.5 by 4.5–6.
Citrus nobilis (mandarin)	11–19.5 by 4.5–6	12–21 by 4.5–5		16–19.5 by 4.5–6.
Coffea arabica (coffee)	15–18.5 by 4.5–6	13.5–16.5 by 5–6		15–18 by 5–6.
Costus speciosus (spiral flag)	10–16.5 by 4.5	12–18 by 4.5–6		15–21.5 by 5–6.
Cucurbita pepo (squash)	8–30 by 3–4.5	10–12.5 by 3–4		
Curculigo sp		14–16.5 by 4.5–6.75.		12–24 by 5.5–6.
Eriobotrya japonica (loquat)		13–19 by 5–6		12–19 by 4.5.
Ficus carica (fig)	10.5–16.5 by 3.5–4.5.	12–15 by 4.5–5	13.5–19.5 by 4.5–6	
Ficus elastica (rubber plant)	10.5–22 by 4–6	12–15 by 4.5–6	13.5–24 by 5–6	11–18 by 4–4.5.
Ficus longifolia	12–15 by 4–6	16–20 by 6		12–20 by 3–4.
Ginkgo biloba	10–22.5 by 4.5–6	11–21 by 5–7.5	11–21 by 4.5–6.5	
Gleditsia triacanthos (honey locust).		13.5–16.5 by 4.5–5	12–24 by 5–7	
Gossypium hirsutum (cotton)	10–42 by 3–9	12–25.5 by 4.5–6	15–18 by 4.5–6	12–19.5 by 4.5.
Hedyscepe sp. (palm)		13–14 by 4–5		13–19.5 by 5–7.5.
Ligustrum vulgare (privet)	12–36 by 6–7	12–21 by 4.5–6	13.5–23 by 4.5–5.5	13.5–18 by 4.5.
Malus sylvestris (apple)	12–18 by 4–4.5	9–18 by 3–6	12–19 by 4.5–6	13.5–19 by 4.5–7.5.
Mangifera sp. (mango)	12–25.5 by 3.5–6	12–25.5 by 3.5–6.		
Maranta arundinacea		5–7.5 by 2–3		
Musa paradisiaca sapientum (banana).	9–28 by 3–6.5	12–19.5 by 4.5–7.5		
Oxycoccus macrocarpus (cranberry).	12–18 by 4.5–6	10.5–21 by 4.5–6	9–20 by 5–7.5	
Persea gratissima (avocado)	12–18 by 4–6	12–18 by 4–5	10.5–16.5 by 3–4.5	13.5–18 by 4.5–7.5.
Phaseolus vulgaris (wax bean)	10.5–16.5 by 4.5–5	12–16.5 by 4.5–6	15–22.5 by 4.5–6	
Phormium tenax	13.5–18 by 4–4.5	13–19.5 by 4–5.5		
Pimenta acris (wild clove)	11–17 by 4–6	10.5–15 by 4–5		
Piper macrophyllum (pepperwort).	10.5–15 by 4–4.5			
Pitcairnia corallina		13.5–18 by 4.5–5		16.5–18 by 4.5.
Psidium guajava (guava)	12–22.5 by 3–4.5	12–19.5 by 4.5–5		13.5–19.5 by 4.5–5.
Ribes oxyacanthoides (gooseberry).	13.5–18 by 4.5–5		13.5–19.5 by 4–5	
Rubus occidentalis (black raspberry).		10.5–18 by 4–6.5	13.5–19.5 by 4.5–5	15–18 by 4.5–5.
Rubus trivialis (white dewberry).	9–16 by 4.5–6	12–22.5 by 3.5–6		
Smilax medica	15–25.5 by 3–4	12–19.5 by 4–5		
Thea japonica (camellia)		12–16 by 4.5–5	12–19.5 by 4.5–6	12–16.5 by 4–6.
Thea sinensis (tea)	12–15 by 3.5–5	15–18 by 4.5–6		10.5–24 by 4–7.5.
Theobroma cacao (chocolate nut).	10.5–13.5 by 4–4.5	13.5–18 by 4.5–6		15–24 by 4.5–7.5.
Vanilla planifolia (vanilla)		12–24 by 4–6		
Vitis labrusca (Concord grape).	10.5–20 by 4.5–6	12–15 by 4.5	12–21 by 4.5–8	

NOTE.—The maximum and minimum measurements given could undoubtedly have been increased in many instances, as no special effort was made to determine the extremes in most cases.

THE PRODUCTION OF PERITHECIA IN GLOMERELLA.

The production of perithecia in Glomerella is a matter of considerable interest and importance, apparently involving some of the fundamental problems of evolution and development. Why is it that the full life cycle of this and various other pyrenomycetes is sometimes completed in pure cultures on sterile media, while at other times only conidia or pycnospores or no fructifications of any kind are formed? Various explanations and suggestions have been made by different writers at different times, but in most cases there has been no sufficient experimental evidence offered to establish fully any of the theories advanced. A brief review of the various attempts which have been made, and the suggestions offered, may be of some interest in this connection. Klebs (53), Smith (83), Brefeld (14), Stoneman (89), Appel and Wollenweber (1), Butler (16), Glück (37), Ihssen (48), and others have discussed the subject.

The production of the sexual fructifications of certain algæ and aquatic fungi may perhaps depend primarily upon factors of nutrition or environment which can be controlled under cultural conditions. The work of Klebs (53), especially, seems to justify such a conclusion. Much more work is necessary, however, to thoroughly verify this and especially to eliminate the possibility of some of the results being due to the use of different races or strains. Kauffmann (50) in the account of his studies on Saprolegnia, expressed the belief that their behavior depended entirely upon definite chemical and physical conditions readily controlled. He also thinks that culture media and conditions could be standardized and safely used as a basis for species segregation. This apparently needs further verification, as Lechmere (57) was unable to obtain the same results with these organisms.

In the case of the sexual forms of algæ some writers have attempted to show that there is a more or less regular periodicity in the appearance of the fertile fructifications of different species. Recent investigations by Danforth (22) appear to throw doubt upon the general application of this view also. However the case may be with the algæ, there is little or no evidence at present available to show that periodicity is an important factor in the production of the perithecial forms of Glomerella and other pyrenomycetes. In the writers' culture work with Glomerella and other genera, such as Guignardia, Melanops, and Cryptosporella, when mature spores are used, they have been unable to find any relation between the time of the collection or the age of the material and the production of the perithecial forms. Under natural conditions it is known that perithecia are in general most abundantly produced in temperate regions during late winter and spring.

Brefeld (14) suggested as the result of observations of ascogenous fructifications under natural conditions that their production depended to some extent on the season of the year and the substratum; but in our experience, cultures made from fresh material collected under natural conditions do not produce perithecia any more frequently from material collected at one time than at another. Various experiments in growing different strains of Glomerella and other pyrenomycetes on various substrata do not indicate that this factor either determines the production of perithecia, though a fruiting strain will fruit more abundantly and freely on some substrata than on others.

It has also been suggested that the nearness or remoteness of origin from ascospores of conidia used in any particular series of cultures might be a factor of importance in determining the course of development of such cultures. The data bearing upon this question which we have obtained from our pedigreed pure-line cultures carried through several generations do not appear to support this theory, though perhaps the available data are not sufficiently numerous to justify definite conclusions.

Of a similar nature is the idea that the production of ascogenous forms occurs only at intervals after the virility or vitality of the conidial or pycnidial form has been greatly reduced by continuous asexual reproduction. There is no known evidence to support this view. Whether there is an actual or potential sexual stimulus or union of nuclei involved in the production of perithecia in Glomerella is not known. No work has been done on the cytological features of the development of the perithecia. As perfect fertile perithecia are produced in abundance in pure cultures from single spores, either conidia or ascospores, it seems certain that no fertilization or union of nuclei between different individuals is necessary. Whatever nuclear unions take place must be between nuclei of the same individual, as is known to be the case in some other ascomycetes.

The most general supposition has perhaps been that which predicated the production of perithecia as dependent upon certain conditions of nutriment or other environment of the organism. This has led to the trial, by most investigators, of various culture media of different constituents in different proportions and also the submission of cultures to various conditions of temperature, air, light, and moisture. Very little success with pyrenomycetous fungi has ever been attained in this direction. In no case have the writers been able to cause perithecia to appear in cultures which did not produce them when grown on corn-meal agar under ordinary laboratory conditions. So far as we have been able to determine, no cases have been reported in which the evidence was sufficiently conclusive to prove that perithecia were produced in artificial cultures as the direct result of modifications of the culture media. Smith (83) reports that the formation of perithecia in a fertile race of Neocosmospora was prevented by the use of strongly alkaline media, but no nonperithecia-forming strains were made to produce perithecia by change of medium.

Appel and Wollenweber (1), in discussing this problem as it relates to Fusarium, Nectria, Neocosmospora, etc., have made some very ingenious suggestions in attempting to account for the production or nonproduction of perithecial forms in cultures. One is that the forms which produce perithecia in cultures on artificial culture media are pure saprophytes, whereas the forms which do not produce perithecia in cultures on artificial culture media are parasites which require the living host or living plant tissues to complete their development. This scarcely accords with the well-established fact that there are all grades and degrees of parasitism among fungi, from the highly specialized obligate forms, such as rusts and smuts, to the weak facultative forms which are only parasitic under certain conditions and in certain stages of their development and may be saprophytic under other conditions or in other stages. A large part of the pyrenomycetes, though parasites, are not of a high type. They frequently pass the early stages of their development—that is, their conidial and pycnidial conditions—as parasites on the living host, whereas they only complete their life history and produce their perithecial or sexual forms upon the dead tissues of the host after it has been killed either by the direct action of the fungus or by some other cause. This fact is emphasized by Massee (59) in his discussion of the evolution of parasitism in fungi. It would not, therefore, appear remarkable if many of these forms should complete their life cycles on sterile culture media containing the essential nutrient substances required by the organism. There is apparently no reason to suppose that the case of Fusarium and Nectria is not directly comparable in this respect with that of Gloeosporium and Glomerella.

There seems to be an abundance of proof to establish the parasitic character of many forms of Gloeosporium. In case of the bitter-rot of the apple, for instance, this parasite has been obtained directly from the tissue of growing fruits before their maturity and when transplanted on artificial culture media has produced perithecia as well as conidia. Perithecia are also frequently produced upon fruits which have been destroyed by the parasite. The suggestion, therefore, that in cases where a Fusarium does not produce perithecia in culture media it is a parasite and that when a Fusarium does produce perithecia in culture media it is a saprophyte, does not appear to accord with what is already known in regard to Glomerella and some other pyrenomycetes.

The case of Neocosmospora, as described by Butler (16), is scarcely more conclusive. The fact that he did not succeed in infecting plants by the use of ascospores of Neocosmospora in the few attempts made does not necessarily prove that this fungus is not a parasite and that it is specifically distinct from the Fusarium form with which he made successful inoculations. As is well known to plant and animal pathologists, there is a great range of variability in the virility or capacity for infection of various races, strains, or forms of what are regarded as the same species; at least they must be so regarded unless some other basis than morphological differences and differences in behavior in culture media can be established as a basis for species segregation. It should be shown either that there are morphological differences between the conidial form of the Fusarium causing the wilt and the conidial form of Neocosmospora sufficient to identify and separate them, or else a large series of inoculation experiments should be carried out, using ascospores and conidia from a variety of sources and including a sufficient number of strains to justify the conclusion that the fungus will not infect the host and may be considered a physiological species.

The other suggestion of the same authors is that the species of Fusarium with which they were working and which did not produce perithecia in cultures may be autonomous forms which have no perithecial stages and that their close resemblance to the conidial forms of Nectria, Neocosmospora, and related genera may be a mere superficial one which does not necessarily imply any direct relationship. This is ingenious also, but unfortunately it is incapable of experimental proof and is not in harmony with the present trend of mycological facts and opinions.

The connection between various conidial and pycnidial forms and their ascogenous stages is being slowly but surely proven by pure-culture methods, and it seems much more natural and reasonable to suppose that the majority at least of the so-called "imperfect fungi" are stages in the life history of ascomycetes and hymenomycetes, though comparatively few have yet been positively connected and the determining factors concerned in the complete development of the organisms are still unknown.

The production of perithecia in the numerous cases of Glomerella which are reported here is evidently a fairly well-fixed hereditary racial character. Having obtained by repeated cultures from different collections a race or strain which produces both conidia and perithecia on culture media, other generations grown from either the conidia or ascospores of this strain continue to produce both spore forms of the fungus indefinitely. In one case, *Glomerella cingulata* from Persea, as already described, a race was grown through 23 successive generations and still produced both conidia and ascospores in as great abundance as at first.

Miss Wakefield (93), as a result of her investigations of *Schizophyllum commune* and *Stereum purpureum*, finds also certain races which show a much greater tendency to produce spores than others under the same conditions of culture. Brefeld (14) states that Penicillium produces ascogenous fructifications at one time while at another, under exactly the same conditions, it produces only conidia.

All the writers' work with Glomerella, as well as with other pyrenomycetes, indicates that the production of perithecia is a hereditary racial character which does not depend primarily on special conditions of nutriment or environment. This conclusion does not, unfortunately, bring us much nearer to the real cause of the phenomenon; it merely eliminates some of the factors heretofore regarded as controlling. The real nature of the inducing causes (for such must be supposed to exist) which determine whether a race shall produce ascogenous or only conidial fructifications is still unknown. Most frequently a strain producing fertile perithecia produces them in abundance. All sorts of intermediate conditions, however, occur from strains which produce only sterile peritheciumlike bodies or sclerotia to those which produce quite constantly great quantities of fertile perithecia. It is, of course, not certain that their behavior in nature corresponds in this respect to that under artificial conditions. Not all of the cultures started with conidia taken from acervuli which were associated with fertile perithecia on the same leaf produced perithecia. There is no certainty, however, that the acervuli and perithecia arose from the same strain, as the manner of the development of the fungus on leaves in moist chamber appears in many cases to indicate that there are more or less numerous points of dormant infection from which the fungus develops and the growth from these finally covers the whole leaf, as shown in Plate V. The intermingling of fructifications originating from different infections perhaps explains why no perithecia were produced in a number of cases in which cultures were made from leaves showing both acervuli and perithecia more or less mixed. No ascogenous strain has ever appeared in any of the hundreds of cultures of conidial strains which have been grown under various conditions on different substrata. Not having had an opportunity to observe the transition from a nonascogenous to an ascogenous race, any attempt to account for this change, which apparently must occur, would be purely hypothetical. The existence of certain intermediate conditions might suggest the gradual development of these ascogenous races, while the failure to produce any evidence that cultural or other environmental influences determine their production seems to indicate a deeper and more obscure cause for their origin. Ascogenous strains may perhaps arise as mutations. This suggestion, however, throws no light upon the cause of their origin.

It is possible that a knowledge of the nuclear phenomena occurring during the stages of development preceding ascus formation may throw some light upon this problem. The possibility of the existence of plus and minus strains uniting as in Mucor has been considered. In many cases where colonies originating from separate ascospores or conidia of perithecial strains meet in a plate culture there is a greater development of perithecia along the line of contact than in other parts of the colonies (Pl. XV); but in no case have perithecia been produced under such conditions when the conidia belonged to a race of the fungus which did not produce perithecia in the separate colonies. Edgerton's (32) experiments along this line already referred to are not conclusive. That no such union of different strains is necessary or essential for the production of perithecia seems certain from the fact that perithecia develop in abundance in a colony derived from a single conidium or ascospore of a perithecial race. Until it has been demonstrated that the increase of perithecia at the point of contact between two colonies is due to nuclear fusions between the two growths it seems preferable to attribute the phenomenon to some simpler cause such as the greater exhaustion of the nutriment at the point or some other slight stimulus. For the present we must admit our utter ignorance of the determining factor or factors concerned in the production of ascogenous fructifications in Glomerella. Certain previously supposed factors, however, such as have already been discussed here, have in most cases been sufficiently tested to justify their elimination. This helps to simplify the problem somewhat and suggests research in other directions which may possibly prove more profitable.

INOCULATION EXPERIMENTS.

Inoculation experiments with Glomerella, either in the field or greenhouse, are not always conclusive. Under proper conditions and with plants known to be free from dormant infections, inoculations, by surface application of spores, under optimum conditions of temperature and moisture, should give the most trustworthy results. To be certain, however, that a plant is free from dormant infection, it must be grown from seed under conditions which would preclude the possibility of infection from any source except the inoculation.

Most of the inoculation experiments of the writers have, however, been made with fruits or plants growing under ordinary laboratory or greenhouse conditions. As it is a practical impossibility to determine whether any particular plant or part of a plant is entirely free from infection, under such conditions, the results obtained can not always be regarded as conclusive. In most of the experiments described here, inoculations were made by insertion of conidia or ascospores of Glomerella in the tissue of the host. Such experiments with immature fruits when made under proper conditions and with sufficient checks are believed to give evidence of some value in determining the host relationships of the organisms. In the case of perfectly mature fruits the significance may not be so great.

Since it has been found that different races or strains of Glomerella vary exceedingly in virility and also that different host plants and varieties of the same host show great differences in susceptibility to any particular race of the fungus, it is clear that success or failure of inoculation experiments may depend, in many cases, on some of these factors. Further discussion of this subject will be found under the heading "Parasitism of Glomerella." Proper conditions of temperature and moisture are also necessary for successful infection either by surface application or puncture. Negative results from inoculation experiments with spores applied to the uninjured surface of a host can not be regarded in all cases as sufficient evidence that the plant is not susceptible to the disease, as the infection may really occur but not develop further at the time for lack of proper temperature, moisture, or host conditions.

In the inoculation experiments in which fruit was used, it was, in most cases, nearly or quite mature. The specimens were always thoroughly washed with corrosive sublimate, 1 to 500, to destroy any spores which might be present on the surface. They were then rinsed with distilled, or sterile, water, and placed in a sterile chamber. A small beaker of water was also placed in the chamber to afford a slight amount of moisture. Unless otherwise stated, the fruit inoculations were always made on picked fruit with a sterilized needle, conidia or ascospores being inserted in a small puncture through the skin. Checks were used which remained free from rot in all cases except where some special statement is made to the contrary.

APPLE TO APPLE.

Various inoculations of apples were made at different times by the writers, conidia of Glomerella from different races or strains being used, in order to compare the rapidity of their development and the effect upon the host. In all the cases in which the inoculations were made by punctures, infection occurred and decay followed. The fruit had the usual appearance of bitter-rot, and acervuli were usually produced. The spots developed to about 1 centimeter in diameter in a week. In some cases development was slower than when inoculations were made with conidia from other host plants.

In three series of experiments conidia were applied to the unbroken skin of nearly mature apples. In none of these cases did any rot follow, although the fruit was kept in a moist chamber for a long period.

Sound apples were inoculated by puncture, using conidia from a single spore culture of the chromogenic form of the apple Glomerella, which has already been described on page 39. Rot developed about each puncture with about the same rapidity as in other cases and acervuli were produced in about three weeks.

Clinton (19) reports successful inoculations of green fruit on trees by inserting conidia in punctures, as indicated in Table IV. He also reports in the same place successful inoculations with ascospores inserted in punctures, and he succeeded in infecting green fruit picked from the trees by placing conidia in drops of water on the unpunctured skin. In two experiments, however, no infection followed spraying the spores on the surface of green fruit. In one experiment he reports successful infection by applying ascospores to the unbroken surface in a drop of water.

Von Schrenk and Spaulding (70) report the successful inoculation of apple limbs by the introduction of ascospores in slits in the bark. They also report successful infections on healthy fruit with spores inserted in punctures and one successful experiment in infecting picked fruit in a moist chamber by spores applied to the unbroken skin. Scott (73) also has made successful inoculations of apples with conidia without puncture.

It will be noted that very few cases have been reported of successful infection of apples without punctures, and much more information is needed in regard to the exact time and method by which infection of the apple takes place. The occurrence of conidia-producing cankers on branches is too rare in most cases, in the East at least, to account for the great prevalence and immense number of the infections which are found during favorable seasons.

APPLE TO BEAN.

Halsted (40) reports successful inoculation of bean pods from apple by the introduction of a portion of the decayed tissue or spores. This is the only successful inoculation of beans with the apple anthracnose that has been reported, and in view of the failure of other investigators to secure the same results it does not seem advisable without verification to give it much weight in determining the specific relationship between the two forms occurring on these hosts.

APPLE TO GRAPE.

On October 14 eight berries of mature Niagara grapes were inoculated by puncture with conidia from apples. Eight others were inoculated by puncture with conidia from a culture. At the end of two weeks the first eight all showed rot and acervuli had formed on five berries. At the end of the same period the other lot all showed rot, but only two bore acervuli.

APPLE TO PUMPKIN.

One mature pumpkin was inoculated by puncture with conidia of Glomerella from an apple. No definite result was obtained, as the pumpkin soon decayed from other causes.

AVOCADO TO APPLE.

On December 17 three apples were inoculated by puncture, using conidia from a fruit of avocado. At the end of the week all showed decayed spots 1 inch in diameter at the point of inoculation with acervuli present in two cases. The other spot was smaller with no acervuli present at first, but many developed a little later.

AVOCADO TO BEAN.

On June 4 six young pods of wax bean were inoculated with conidia. No signs of infection ever appeared.

AVOCADO TO CABBAGE.

On November 8 young cabbage plants, bearing 8 to 10 leaves, were inoculated with conidia from a pure culture. Inoculations were made by puncture and by surface application. No signs of infection ever appeared on the inoculated leaves.

AVOCADO TO COTTON.

On April 1 three open cotton flowers were inoculated by applying conidia in a drop of sterile water to the stigma of the flower. The flowers were then covered with paper bags. No signs of infection had appeared at the end of two weeks, and no conidia developed on the bolls when removed and placed in moist chamber.

On November 8 bolls one-half grown were inoculated with conidia from a pure culture. Part of the inoculations were made on the surface, the others by puncture. No signs of infection appeared at the end of a month.

AVOCADO TO RUBBER PLANT.

Leaves were inoculated with conidia from pure culture, some applied to the surface and some by punctures. No signs of infection followed in either case.

AVOCADO TO TEA.

On November 8 young leaves were inoculated by both surface and puncture methods with conidia from a pure culture. No signs of infection appeared at the end of a month.

BEAN TO APPLE.

On September 30 four apples were inoculated by puncture with conidia from a bean pod. No signs of infection had appeared at the end of a month.

On July 25 seven apples were inoculated by puncture with conidia from a green bean pod. These fruits decayed after a month but no acervuli formed. Cultures made from the decayed spots produced only a sterile mycelium somewhat resembling that of *Gloeosporium lindemuthianum*. Positive identification was impossible without spore formation.

On October 4 twelve Willow Twig apples were inoculated by puncture with conidia from a bean pod. No signs of infection followed.

On October 6 four Willow Twig apples were inoculated on the surface with conidia from a bean pod. At the end of a month no signs of infection had appeared. The same experiment was repeated November 2 with the same result.

On October 6 four apples were inoculated by punctures with conidia from a bean pod. No signs of infection had appeared at the end of a month.

In December three Willow Twig apples were inoculated by puncture with conidia from a bean pod. No signs of decay occurred at the end of a month.

Later, three other mature apples were inoculated by puncture with conidia from culture. No decay followed and no acervuli developed. Twenty-nine other apples were inoculated by puncture with conidia of the bean Glomerella at different times during the season. In no case did decay or development of acervuli follow. In eight other cases also where conidia were applied to the surface of apples no infection occurred. These experiments seem to indicate that the Glomerella on the bean is physiologically different from that on the apple.

BEAN TO BEAN.

On June 4 six young pods of wax beans 2 inches long were inoculated by applying conidia from a bean pod to the surface. The plants were covered with a bell jar. No signs of infection ever appeared on these pods.

On June 5 the same experiment was repeated with the same result. The reason for the failure of these inoculations is not clear.

BEAN TO COTTON.

On July 16 four young bolls were inoculated by puncture with conidia from a bean pod. Small, dark, sunken areas developed about the point of inoculation in all, the same as with inoculations from cotton to cotton made at the same time. No acervuli appeared except on one of the bolls after removal to a moist chamber. These acervuli may not have arisen from the original inoculation from the bean.

BEAN TO PUMPKIN.

A mature pumpkin was inoculated by puncture with conidia from a culture from bean. No signs of infection followed.

BEAN TO HUBBARD SQUASH.

A mature squash was inoculated by puncture with conidia from a culture of the bean Glomerella. No decay followed and no acervuli formed.

BEAN TO TOMATO.

Four green tomato fruits were inoculated by puncture with conidia from wax beans. No decay followed and no acervuli formed.

BEAN TO WATERMELON.

A nearly mature watermelon was inoculated by puncture with conidia from a bean culture. No signs of infection followed.

It will be observed that no successful inoculations from bean to cucurbits were made. These results agree with those of Edgerton (30) but not with those of Halsted (39).

CAMELLIA TO BEAN.

On June 4 five young pods of bean grown in the greenhouse were inoculated by surface application of conidia in sterile water. No signs of infection followed.

On June 5 the same experiment was repeated with six pods, but without success.

CARYOTA TO COTTON.

On April 1 stigmas of three cotton flowers were inoculated by applying conidia in sterile water to the surface. The young bolls soon dropped, but when placed in moist chamber no conidia developed.

CHERIMOYA TO APPLE.

On October 2 three apples were inoculated by puncture with conidia from a culture. Decay followed about the points of inoculation in one week and acervuli were produced.

CHERIMOYA TO GRAPE.

On October 4 eight mature berries were inoculated by puncture with conidia from a culture. At the end of two weeks all the grapes were decayed and seven showed acervuli.

CINNAMON TO COTTON.

On April 1 three flowers were inoculated by the application of conidia in sterile water to the stigmas. No signs of infection followed, but the young bolls soon fell off. These bolls were kept in moist chamber for several weeks, but no conidia or acervuli developed.

COTTON TO APPLE.

Mature fruit was inoculated by puncture with conidia from a pure culture of the cotton fungus. A slight decay appeared in two weeks and a few acervuli with setæ bearing spores were found. At the end of a month the decayed spots had become larger and colored sporophores were also found mixed with the setæ.

On October 6 four apples were inoculated by applying conidia from cotton cultures to the surface. At the end of three weeks there was no sign of infection or decay.

On July 25 four apples were inoculated by puncture with conidia from a cotton boll. A slight decay appeared on two at the end of a month. At the end of one and one-half months the spots were three-fourths of an inch in diameter. Cultures made from the pulp from these spots produced acervuli and conidia with setæ, also brown septate conidia, such as are mentioned by Clinton (19). Two apples inoculated later in the same way produced practically the same result. The development of rot was very slow.

On October 6 four apples were inoculated by puncture using conidia from cultures made from the apple which was originally inoculated from cotton. Three of these apples showed small rotten spots at the end of 8 days. At the end of 20 days all showed rot and two produced acervuli. No typical setæ were found, but some brownish sporophores occurred which were rather intermediate in form between sporophores and setæ. This second generation of the cotton fungus on the apple developed much more rapidly than the first generation and indicated the possibility of its soon developing fully as fast as the form from the apple. This experiment and similar ones with other hosts appear to indicate that these organisms under certain conditions may rather quickly adapt themselves to different hosts though retaining their specific morphological characters. These results also suggest the possibility of the apple acting as a bridging host in some instances. This is in accord with the work of Salmon (68) on mildews and with that of Ward (94) on rusts.

COTTON TO BEAN.

On June 4 six young pods from a greenhouse plant were inoculated by applying conidia in sterile water from a cotton boll to the surface. No signs of infection ever appeared.

COTTON TO COTTON.

On March 19 five flowers were inoculated by applying conidia in sterile water from a cotton boll to the stigmas. All the bolls soon turned black and nearly all dropped off. One boll that remained on the plant about two weeks before it died became half covered with acervuli.

On June 24 six young bolls were inoculated by puncture with conidia from a cotton boll. In about two weeks small, dark, sunken spots had formed on all and four showed acervuli.

COTTON TO PUMPKIN.

On November 2 a pumpkin was inoculated by puncture with conidia from a pure culture of the cotton fungus. No signs of infection ever appeared.

COTTON TO HUBBARD SQUASH.

A squash was inoculated by puncture with conidia from a pure culture. No signs of infection ever appeared.

COTTON TO WATERMELON.

On November 2 a watermelon was inoculated by puncture with conidia from a pure culture from cotton. No rot followed, but a slight development of hyphæ and a few acervuli formed at the puncture. Spore-bearing setæ were present in these acervuli, as is usually the case with *Glomerella gossypii*.

CRANBERRY TO APPLE.

On April 27 six sound apples were inoculated by puncture with conidia from a pure culture. No rot or acervuli had developed at the end of a month. Later inoculations produced a slight decay in one instance and a few acervuli formed.

CRANBERRY TO SWEET PEA.

On April 6 stems and young leaves of young plants in the greenhouse were inoculated with ascospores in sterile water applied to the surface. No signs of infection ever appeared.

CURCULIGO TO COTTON.

On April 2 three flowers in greenhouse were inoculated by applying conidia in sterile water to the stigmas. No signs of infection appeared, but the young bolls dropped off. They were placed in a moist chamber, but no acervuli developed.

DEWBERRY TO APPLE.

On October 2 three apples were inoculated by puncture with conidia from a culture from dewberry. At the end of a month only one apple showed a decayed spot, 1.75 inches in diameter. Small decayed spots occurred on the other two apples at points of inoculation 26 days later.

On October 12 four Willow Twig apples were inoculated by puncture with conidia from a culture. At the end of three weeks only one fruit showed development of rot, about 1.75 inches in diameter.

On October 26 three apples were inoculated by puncture with conidia from culture from the apple previously inoculated from dewberry. Only a slight decay occurred about the point of inoculation after several weeks and no acervuli formed. Cultures made from these decayed spots produced acervuli.

DEWBERRY TO APPLE TO AGAR TO APPLE.

On December 7 three apples were inoculated by puncture with conidia from an agar culture made from the first apples inoculated from the dewberry. Infection followed in all cases. Decayed spots 0.5 to 0.75 inch in diameter developed in six days, but no acervuli were produced.

DEWBERRY TO APPLE TO APPLE TO AGAR TO APPLE.

On January 3 three apples were inoculated by puncture with conidia from a pure culture made from the second generation of the dewberry fungus on apples. Infection followed in all cases. The decayed spots developed more rapidly than in the previous generation and abundant acervuli were formed.

On January 10 three apples were inoculated by puncture with conidia from a culture from the second generation grown on apple. Infection followed in all cases. Decayed spots an inch in diameter developed in 10 days and numerous acervuli appeared. These experiments seem to indicate that the dewberry form of Glomerella becomes quickly adapted to growth on apples, developing in the third generation about as rapidly as the fungus taken directly from apples and producing typical rot and acervuli.

DEWBERRY TO GRAPE.

On October 16 eight berries were inoculated by puncture with conidia from a culture from the same strain of the dewberry Gloeosporium used in the inoculations with apples. At the end of two weeks some rot was found, but no acervuli were ever produced.

FIG TO APPLE.

On September 14 four apples inoculated by puncture with conidia from a pure culture from the fig produced decay of the usual appearance of bitter rot, and acervuli were formed.

On October 2 three apples were inoculated by puncture with conidia from a pure culture from the fig. Infection followed in all cases and decay developed as rapidly as in inoculations made directly from apple to apple and typical acervuli also developed as shown in Plate XVI, figure 7.

FIG TO FIG.

Eight nearly mature figs were inoculated, four by puncture with conidia from cultures and four by application of the same to the unbroken surface of the fruit. Rot developed in all cases and acervuli formed. There is some doubt about this experiment, however, on account of the fact that three out of the seven checks used also developed rot.

FIG TO GRAPE.

Eight mature berries were inoculated by puncture with conidia from a pure culture from the fig. Most of the berries were rotten at the end of three weeks and three showed acervuli.

FICUS LONGIFOLIA TO RUBBER PLANT.

The under side of a young leaf attached to a plant was inoculated by placing conidia from a pure culture in sterile water on the uninjured surface and covering the spot with a Van Tiegham cell. At the end of 24 days there was no sign of infection. The leaf was then removed from the plant and placed in a moist chamber. Acervuli developed on the inoculated spot after two weeks but not on the check spot covered in the same way.

GOOSEBERRY TO APPLE.

On December 7 three apples were inoculated by puncture using hyphæ and probably ascospores from a pure culture containing masses of mature perithecia. On December 15 two of the apples showed rotten spots 1 cm. in diameter at the points of inoculation and the third a discoloration of the skin. By January 7 the first two apples were half rotten and the third about one-third decayed, and two of them produced acervuli. Cultures made from these apples produced both acervuli and perithecia of the fungus, the perithecia predominating.

GRAPE TO APPLE.

In four different experiments in which apples were inoculated by puncture with conidia from cultures from grapes or direct from the host typical bitter-rot followed and acervuli developed.

On August 19 eight Smokehouse apples were inoculated with conidia from rotten grapes from another source. This strain of the fungus appeared to be weak or not adapted to development on apples. Rot developed on only two of the inoculated fruits. The spots were small and increased very slowly and no acervuli were produced. Cultures were made from these spots.

GRAPE TO APPLE TO AGAR TO APPLE.

On August 24 six Smokehouse apples were inoculated by puncture with conidia from the culture made from apples inoculated from grape as mentioned above. Decay developed very slowly about the point of inoculation but a little faster than in generation 1. Finally some acervuli were produced on all but one of the apples.

On September 18 the above experiment was repeated with six Smokehouse apples. The development of rot this time was somewhat faster than before and acervuli developed on all.

GRAPE TO AGAR TO APPLE TO AGAR TO APPLE TO APPLE.

Four apples were inoculated by puncture with conidia from an apple inoculated with the third generation of the fungus from the grape. Rot developed about as rapidly at the point of inoculation on these fruits as is usual in transfers directly from apple to apple and at the end of 8 days acervuli were found.

GRAPE TO AGAR TO APPLE TO GRAPE.

On September 23 twelve ripe berries were inoculated by puncture with conidia from an apple. Only four developed the usual rot followed by acervuli. The others softened somewhat but no acervuli formed.

GRAPE TO AGAR TO GRAPE.

On September 23 twelve ripe berries were inoculated by puncture with conidia from a culture from a grape. At the end of two weeks five were rotten and acervuli had formed. Seven of these eventually decayed and showed acervuli.

GRAPE TO AGAR TO APPLE TO TOMATO.

On September 29 four green tomatoes were inoculated by puncture with conidia from a culture from a grape. Slight decay followed in only one case, but perhaps not from the inoculation. No acervuli were ever produced.

GRAPE TO PUMPKIN.

A pumpkin was inoculated by puncture with conidia from a culture from a grape. Rot developed rapidly and acervuli formed.

GRAPE TO HUBBARD SQUASH.

A nearly mature squash was inoculated by puncture with conidia from a culture from a grape. Rot developed very slowly at one point of inoculation only. A few acervuli were found at the end of a month.

GRAPE TO WATERMELON.

A nearly mature watermelon was inoculated with conidia by puncture from a culture from a grape. Rot developed rapidly at the point of inoculation and numerous acervuli formed.

GUAVA TO APPLE.

Two apples were inoculated by puncture with conidia from a culture from leaves of guava. Rot developed at the points of inoculation about as rapidly as in the case of transfers from apple to apple. Acervuli were present at the end of a week. No setæ were found.

GUAVA TO BEAN.

Six young pods of a wax bean from the greenhouse were inoculated by surface application of conidia from guava. No signs of infection ever followed.

GUAVA TO COTTON.

Three flowers of a cotton plant from the greenhouse were inoculated by applying conidia from guava to the surface of the pistil. No signs of infection were found at the end of two weeks, but two of the small bolls which developed from the inoculated flowers developed acervuli with setæ when placed in a moist chamber.

GUAVA TO PUMPKIN.

A pumpkin was inoculated by puncture with conidia from a culture from guava leaves. Rot developed rapidly and acervuli were produced in abundance.

GUAVA TO HUBBARD SQUASH.

A squash was inoculated by puncture with conidia from a culture from guava leaves. No rot appeared and no acervuli developed.

GUAVA TO WATERMELON.

A nearly mature watermelon was inoculated by puncture with conidia from a culture from guava leaves. Rot developed rather rapidly. Numerous acervuli were produced, as shown in Plate XVIII.

LEMON TO APPLE.

On September 14 four Willow Twig apples were inoculated by puncture with conidia from a culture from a lemon. Rot of the usual appearance developed rapidly in all cases and typical acervuli formed. On October 2 three apples were inoculated by puncture with conidia from a culture. Rot developed in all cases. The spots were 2 centimeters in diameter at the end of a week and acervuli were present.

LEMON TO CABBAGE.

On December 17 leaves of a young cabbage plant in the greenhouse were inoculated by puncture with conidia from a lemon leaf. No signs of infection ever followed.

LEMON TO COTTON.

On December 17 leaves and bolls were inoculated by puncture with conidia from lemon leaves. No signs of infection were found at the end of a month.

LEMON TO CRANBERRY.

On December 17 leaves of a plant from the greenhouse were inoculated by puncture with conidia from a lemon leaf. No signs of infection were ever seen.

LEMON TO GRAPE.

On October 14 eight mature berries of Niagara grapes were inoculated by puncture with conidia from a culture. At the end of two weeks most of the berries were rotten and three bore acervuli.

LEMON TO ORANGE.

On December 17 orange leaves were inoculated by puncture with conidia from a lemon leaf. No signs of infection ever followed.

LEMON TO RUBBER PLANT.

On December 17 leaves on a living plant were inoculated by puncture with conidia from a lemon leaf. No signs of infection ever followed.

LEMON TO TEA.

On December 17 leaves of a living plant were inoculated by puncture with conidia from a lemon leaf. No signs of infection were found at the end of a month.

LOQUAT TO BEAN.

On June 4 six young pods from a greenhouse plant were inoculated by immersion in sterile water containing conidia. No signs of infection ever followed.

MANDARIN TO BEAN.

On June 4 six young pods from a greenhouse plant were inoculated by immersing beans in sterile water containing conidia. No signs of infection ever appeared.

MANDARIN TO COTTON.

On April 1 flowers of a greenhouse plant were inoculated by applying conidia to the stigmas. No signs of infection followed, but the young bolls soon dropped off. They were placed in a moist chamber, but no Gloeosporium developed.

MARANTA TO COTTON.

Stigmas of three flowers of a greenhouse plant were inoculated in the same manner as above. No signs of infection followed, but the young bolls dropped off. They were placed in a moist chamber, but no Gloeosporium developed.

ORANGE TO BEAN.

On June 5 six young pods on a greenhouse plant were inoculated by immersion in sterile water with conidia. No signs of infection ever appeared.

ORANGE TO COTTON.

On April 1 three flowers were inoculated by applying conidia to the stigmas. No indications of infection appeared, but the young bolls soon dropped. These bolls were kept in a moist chamber, but no Gloeosporium developed.

On June 24 five young bolls were inoculated by puncture with conidia from this host. Two developed slight decay and when removed to a moist chamber acervuli developed. Six others inoculated in the same way a little later showed scarcely any signs of decay about the point of inoculation but developed acervuli when removed to a moist chamber.

ORANGE TO RUBBER PLANT.

On February 4 two leaves of a small plant in the laboratory were inoculated by making a slight incision across the midrib near the tip and immersing the leaves in sterile water containing conidia from a culture. After five weeks no signs of infection were apparent. The leaf was removed from the plant, its surface thoroughly washed with corrosive-sublimate solution, and placed in a moist chamber. Twelve days afterwards, the leaf showed abundant acervuli extending about 3 inches from the tip. The two checks treated in the same manner throughout produced no Gloeosporium when kept in a moist chamber.

ORANGE TO TEA.

On February 4 two leaves of a growing plant in the laboratory were inoculated by making a slight incision in the midrib and immersing the leaf in sterile water containing conidia. A check was also treated in the same manner but not inoculated. The inoculated leaf developed immature acervuli on a small dead area surrounding the puncture while still attached to the plant. The check leaf was removed and placed in a moist chamber, but no Gloeosporium developed. Another leaf, however, on the same plant which appeared healthy was removed and placed in a moist chamber and this developed abundant acervuli, which indicates that it is practically impossible to determine whether or not a leaf or any portion of a plant already contains the fungus in a dormant condition. Results of experiments of this kind are thus shown to be somewhat uncertain.

PEPPERWORT TO COTTON.

Stigmas of two cotton flowers from the greenhouse were inoculated by the application of conidia in sterile water. The young bolls soon dropped off. They were kept in a moist chamber but no Gloeosporium developed.

PHORMIUM TO CABBAGE.

Five young plants in pots in the laboratory were sprayed with distilled water containing conidia and then covered with a bell jar. Leaves of both inoculated plants and checks soon turned yellow and dropped off. All these leaves were placed in moist chambers. Acervuli of Gloeosporium appeared on the inoculated leaves but not on the check. In two cases acervuli were produced on the inoculated leaves while still attached to the plant.

PITCAIRNIA TO BEAN.

Six young pods on a plant in the greenhouse were inoculated by immersion in sterile water containing conidia. No signs of infection ever appeared.

PITCAIRNIA TO COTTON.

The stigmas of two flowers of a greenhouse plant were inoculated with conidia in sterile water. The young bolls soon dropped off. These were placed in a moist chamber, but no Gloeosporium ever developed.

POMELO TO APPLE.

Three apples were inoculated by puncture with conidia from a culture. Infection followed in all cases. Spots 2 centimeters in diameter developed at the end of a week and acervuli formed.

POMELO TO GRAPE.

Eight mature berries of a Niagara grape were inoculated by puncture with conidia from a culture. At the end of two weeks the berries were mostly rotten, and acervuli were found on six of them.

POMELO TO POMELO.

Two sound fruits were inoculated by applying conidia in sterile water to the uninjured surface. The conidia germinated, and a slight development of mycelium with scattered conidia and chlamydospores appeared on the surface but the tissue beneath remained sound. No rot developed. In another case the same experiment was tried, applying the spores to the surface which had been injured by red spiders. The results were exactly the same as in the case just mentioned. No rot developed.

PRIVET TO BEAN.

Six young pods from a greenhouse plant were inoculated by immersion in sterile water containing conidia. No signs of infection ever appeared.

RUBBER PLANT TO FIG.

Four figs were inoculated by puncture with conidia from a leaf. Rot developed in all cases. Four other fruits were inoculated by application of conidia in sterile water to the uninjured surface of the figs. Rot developed but did not appear to start immediately at the point of application of the spores and as one of the checks in this experiment also developed rot the results are uncertain. Both lots of figs are shown in Plate XVII.

INOCULATION EXPERIMENTS BY OTHER INVESTIGATORS.

In order to compare and render convenient and accessible the complete results of experimental inoculations with Glomerella and its conidial forms up to the present time, the published data of other investigators have been arranged in tabular form. Where particular facts are wanting they are not given by the authors cited.

TABLE IV.—*Results of inoculations as reported by other investigators.*

Host.			Method of inoculation.	Material used.[1]	Source of material.	Result.	Experimenter.
Original.	Inoculated.	Part inoculated.					
Apple	Apple	Green fruit	Puncture	C.		Success	Clinton, 1902.
Do	do	Fruit	do	A.		do	Do.
Do	do	Green fruit	Surface	C.		do	Do.
Do	do	do	do	C.		Failure	Do.
Do	do	Fruit on tree	do	C.		do	Do.
Do	do	Fruit	do	A.		Success	Do.
Do	do	do	do	C.		do	Hasselbring, 1906.
Do	do	do	do	C.	Canker	do	Scott, 1906.
Do	do	Branches	Puncture	A.	Pure culture	do	Spaulding and Von Schrenk, 1903.
Do	do	do	do	C.	do	do	Do.
Do	do	Fruit	do	C.	do	do	Do.
Do	do	do	do	C.	Canker	do	Do.
Do	do	Ripe fruit		C.	Pure culture	do	Edgerton, 1911.
Do	do	Fruit on tree	Puncture	C.		do	Taubenhaus, 1911.
Do	Crab apple	Ripe fruit	Surface	C.		do	Clinton, 1902.
Do	Banana	Fruit	do	C.	Host	do	Cobb, 1904.
Do	do	do	do	C. or H.	do	do	Halsted, 1892.
Do	do	do		C.	do	Failure	Laubert, 1910.
Do	Barberry	do	Surface	C.		Success	Hasselbring, 1906.
Do	Bean	do	Puncture	C.	Host	do	Halsted, 1892.
Do	Bush bean	Pods on vine	Surface	C.		Failure	Taubenhaus, 1911.
Do	Cherry	Fruit	Puncture	C.	Host	Success	Cobb, 1892.
Do	do	do	do	C.	do	do	Cobb, 1904.
Do	Eggplant	do	do	C. or H.	do	do	Halsted, 1892.
Do	Guava	do	do	C.	do	do	Cobb, 1904.
Do	Hawthorn	do	do	C.	do	do	Do.
Do	Lemon	do	do	C. or H.	do	do	Halsted, 1892.
Do	Lima bean	Pods on vine	do	C.		do	Taubenhaus, 1911.
Do	Mango	Fruit	do	C.	Host	do	Cobb, 1892.
Do	do	do	do	C.	do	do	Cobb, 1904.
Do	Nectarine	do	do	C.	do	do	Cobb, 1892.
Do	do	do	do	C.	do	do	Cobb, 1904.
Do	Peach	Green fruit	do	C.		do	Clinton, 1902.
Do	do	do	do	C.		do	Do.
Do	do	do	Surface	C.		do	Do.
Do	do	Fruit	Puncture	C.	Host	do	Cobb, 1892.
Do	do	do	do	C.	do	do	Cobb, 1904.
Do	do	do	do	C. or H.	do	do	Halsted, 1892.
Do	Pear	Branch			do	Doubtful	Burrill, 1907.
Do	do	Ripe fruit	Puncture	C.		Success	Clinton, 1902.
Do	do	Green fruit	do	C.		do	Do.
Do	do	Ripe fruit	Surface	C.		Doubtful	Do.
Do	do	Fruit	Puncture	C.	Host	Success	Cobb, 1892.
Do	do	do	do	C.	do	do	Cobb, 1904.
Do	do	do	do	C.	do	do	Halsted, 1892.
Do	do	Fruit on tree	do	C.		do	Taubenhaus, 1911.
Do	Pepper	Fruit	do	C	Host	do	Cobb, 1904.
Do	do	do	do	C. or H.		do	Halsted, 1892.
Do	Persimmon	do	do	do		do	Do.
Do	Plum	do	do	C.	Host	do	Cobb, 1892.
Do	do	do	do	C.	do	do	Cobb, 1904.

[1] A.=ascospores; C.=conidia; H.=hyphæ.

TABLE IV.—*Results of inoculations as reported by other investigators*—Continued.

Host.			Method of inoculation.	Material used.	Source of material.	Result.	Experimenter.
Original.	Inoculated.	Part inoculated.					
Apple	Plum to tomato.	Fruit	Puncture	C	Host	Success	Cobb, 1904.
Do	Quince	Green fruit	do	C		Failure	Clinton, 1902.
Do	do	Fruit	do	C	Host	Success	Cobb, 1904.
Do	do	do	do	C. or H.		do	Halsted, 1892.
Do	Sweet pea	Young leaves	Surface	C	Culture	do	Edgerton, 1908.
Do	do	Seedlings	do	C	Host	do	Sheldon, 1905.
Do	do	do	Puncture	C		do	Taubenhaus, 1911.
Do	do	do	Surface	C		do	Do.
Do	Tomato	Green fruit	Puncture	C		do	Clinton, 1902.
Do	do	Fruit	do	C	Host	do	Cobb, 1904.
Do	do	do	do	C. or H.		do	Halsted, 1892.
Asclepias	Apple	do	do	C		Doubtful.	Edgerton, 1908.
Avocado	Pear	Fruit on tree	do	C		Rot, but not typical.	Taubenhaus, 1911.
Do	Sweet pea	Seedlings	Surface	C		Failure	Do.
Do	do	do	Puncture	C		do	Do.
Banana	Apple	Fruit	do	C	Host	do	Cobb, 1904.
Do	do	do		C		do	Laubert, 1910.
Do	Date to plum	do	Puncture	C	Host	Success	Cobb, 1904.
Do	Lemon	do	do	C	do	Doubtful.	Do.
Do	Passion fruit	do	do	C	do	do	Do.
Do	do	do	do	C	do	Very doubtful.	Do.
Do	Peach	do	do	C	do	(1)	Do.
Do	Pear	do	do	C	do	Success	Do.
Do	Quince	do	do	C	do	do	Do.
Bean	Alfalfa	Stem and leaves.	Surface	C		Failure	Edgerton, 1910.
Do	Apple	Fruit		C		do	Edgerton, 1908.
Do	do	Ripe fruit		C	Pure culture	do	Edgerton, 1911.
Do	Bean	Leaves	Surface	C	Culture	Success	Edgerton, 1910.
Do	do	Stems	do	C	do	do	Do.
Do	do	Pods	do	C	do	do	Do.
Do	Citron [2]	Fruit	Puncture	C	Host	do	Halsted, 1893.
Do	Cotton		Surface	C		Failure	Edgerton, 1910.
Do	Cucumber	Leaves, stems, fruit.	do	C		do	Do.
Do	Eggplant	Fruit	Puncture	C. or H.	Host	Success	Halsted, 1892.
Do	Pea	Leaves	Surface	C		Failure	Edgerton, 1910.
Do	Pear	Fruit	Puncture	C. or H.	Host	Success	Halsted, 1892.
Do	Pepper	do	do	do	do	do	Do.
Do	Persimmon	do	do	do	do	do	Do.
Clover	Apple	Ripe fruit		C	Pure culture	Failure	Edgerton, 1911.
Coffee	do	Fruit		C		Success	Edgerton, 1908.
Do	Fig	Leaves		C		do	Do.
Cotton	Apple	Fruit		C		do [3]	Do.
Do	do	Ripe fruit		C	Pure culture	Failure	Edgerton, 1911.
Do	Bean	Seed	Surface	C		do	Edgerton, 1910.
Do	Cotton	Very young bolls.	do	C	Culture	(4)	Barre, 1909.
Do	do	Stems	Puncture	C		Failure	Do.
Do	do	Leaves	do	C		do	Do.
Do	do	Petioles	Cut	C		Success	Do.
Do	do	Flowers	Surface	C		(5)	Do.
Do	Fig	Green fruit		C	Pure culture	Partial success.	Edgerton, 1911.

[1] Development slow.
[2] *Citrullus vulgaris* var.
[3] Takes poorly.
[4] 60 per cent infected.
[5] 37 per cent infected.

TABLE IV.—*Results of inoculations as reported by other investigators*—Continued.

Host.			Method of inoculation.	Material used.	Source of material.	Result.	Experimenter.
Original.	Inoculated.	Part inoculated.					
Dracaena	Apple	Fruit		C		Success	Edgerton, 1908.
Do	Fig	Leaves		C		do	Do.
Eggplant	Bean	Pods ?	Puncture	C. or H.	Host	do	Halsted, 1892.
Do	Pepper	Fruit	do	C	do	do	Do.
Fig	Apple	Ripe fruit		C	Pure culture	do	Edgerton, 1911.
Do	Bean	Seeds, stems, leaves.	Surface	C		Failure	Edgerton, 1910.
Do	Fig	Green fruit		C	Pure culture	Success	Edgerton, 1911.
Do	do	do		C	Culture from branch.	do	Do.
Guava	Apple	Fruit	Puncture	C	Host	Success	Cobb, 1904.
Do	do	Picked fruit	do	C	Culture	do	Sheldon, 1906.
Do	do	Unpicked fruit.	do	C	do	do	Do.
Do	do	Young unpicked fruit.	do	C		Failure	Do.
Do	do	Picked fruit.	do	C		Success	Do.
Do	do	Twigs	do	C		Failure	Do.
Do	Banana	Fruit	do	C	Host	Success	Cobb, 1904.
Do	Bush bean	Pods on vine	do	C		do	Taubenhaus, 1911.
Do	Damson plum.	Fruit	do	C	Culture	do	Sheldon, 1906.
Do	Apple to hawthorn.	do	do	C	Host	do	Cobb, 1904.
Do	Passion vine	do	do	C	do	Failure	Do.
Do	Pear	do	do	C	do	Success	Do.
Do	do	do	do	C	do	Very doubtful.	Do.
Do	do	Fruit on tree	do	C		Rot, but not typical.	Taubenhaus, 1911.
Do	Quince	Fruit	do	C	Host	Success	Cobb, 1904.
Do	Quince to guava.	do	do	C	do	do	Do.
Do	Sweet pea	Seedling	do	C		Failure	Taubenhaus, 1911.
Do	do	do	Surface	C		do	Do.
Kentia	Apple	Green fruit	Puncture	C	Host	Success	Cobb, 1904.
Mandrake	do	Fruit		C		do	Taubenhaus, 1911.
Do	Lima bean	Pods on vine	Puncture	C		do	Do.
Do	Pear	do	do	C		do	Do.
Do	Sweet pea	Seedling	do	C		do	Do.
Do	do	Seedling	Surface	C		do	Do.
Oak gall	Apple	Fruit		C		do	Do.
Do	Lima bean	Pods on vine	Puncture	C		do	Do.
Do	Pear	Fruit	do	C		do	Do.
Do	Sweet pea		do	C		do	Do.
Do	do	Seedling	Surface	C		do	Do.
Orange	Apple	Fruit		C		Doubtful.	Edgerton, 1908.
Passion vine	do	do	Puncture	C	Host	Failure	Cobb, 1904.
Do	Date to plum.	do	do	C	do	do	Do.
Do	Guava	do	do	C	do	do	Do.
Do	Peach	do	do	C	do	do	Do.
Do	Pear	do	do	C	do	do	Do.
Passion leaves	do	do	do	C	do	Success	Do.
Passion vine	Pepper	do	do	C	do	Failure	Do.
Do	Pineapple	do	do	C	do	do	Do.
Do	Tomato	do	do	C	do	Success	Do.
Do	Quince	do	do	C	do	Failure	Do.
Pear	Banana	do	do	C. or H.		Success	Halsted, 1892.
Do	Citron[1]	do	do	do		do	Do.
Do	Lemon	do	do	do		do	Do.
Do	Pepper	do	do	do		do	Do.
Do	Tomato	do	do	do		do	Do.
Pepper	Apple	do	do	C	Host	do	Cobb, 1904.
Do	do	do	do	C. or H.		do	Halsted, 1892.
Do	do	Ripe fruit		C	Pure culture	do	Edgerton, 1911.

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[1] *Citrullus vulgaris* var.

TABLE IV.—*Results of inoculations as reported by other investigators*—Continued.

Host.			Method of inoculation.	Material used.	Source of material.	Result.	Experimenter.
Original.	Inoculated.	Part inoculated.					
Pepper	Banana	Fruit	Puncture	C. or H.		Success	Halsted, 1892.
Do	Bean	Stem and leaves.	Surface	C.		Failure.	Edgerton, 1910.
Do	do	Pod	Puncture	C. or H.		Success	Halsted, 1892.
Do	Fig	Green fruit		C.	Pure culture	do	Edgerton, 1911.
Do	Pear	Fruit	Puncture	C.		do	Halsted, 1892.
Do	Persimmon	do	do	C.		do	Do.
Poplar	Apple	Ripe fruit		C.	Pure culture	Partial success.	Edgerton, 1911.
Quince	do	Fruit	Puncture	C.	Host	Success	Cobb, 1904.
Raspberry	do	do		C.		do	Edgerton, 1908.
Rose	Bean	Picked pods.	Surface	C.	Culture	Failure	Edgerton, 1910.
Rubber plant.	Rubber plant	Detached leaves.	do	A.	do	Success	Koorders, 1907.
Do	do	Seedling leaves.	do	A.	do	do	Do.
Sarracinia	Fig	Leaves		C.		do	Edgerton, 1908.
Sassafras	Apple	Fruit		C.		do	Taubenhaus, 1911.
Do	Lima bean	Pods on vine	Puncture	C.		do	Do.
Do	Pear	Fruit	do	C.		do	Do.
Do	Sweet pea	Seedling	do	C.		do	Do.
Do	do	Seedling	do	C.		do	Do.
Do	do	do	Surface	C.		do	Do.
Silver maple	Apple	Ripe fruit		C.	Pure culture	do	Edgerton, 1911.
Do	Fig	Green fruit		C.	do	do	Do.
Sweet pea	Apple	Fruit		C.		do	Taubenhaus, 1911.
Do	do	Fruit on tree	Puncture	C.		do	Do.
Do	Bush bean	Pods on vine	do	C.		do	Do.
Do	do	do	Surface	C.		Failure	Do.
Do	Lima bean	do	Puncture	C.		Success	Do.
Tomato	Apple	do	do	C. or H.		do	Halsted, 1892
Do	Banana	do	do	do		do	Do.
Do	Bean	Pod	do	do		do	Do.
Do	Eggplant	Fruit	do	do		do	Do.
Do	Pear	do	do	do		do	Do.
Do	Pepper	do	do	C.	Culture	do	Chester, 1893.
Do	do	do	do	C.		do	Do.
Do	do	do	Surface	C.		Failure	Do.
Do	Pepper to pepper.	do	Puncture	C.		Success	Do.
Do	Pepper to squash.	do	do	C.		Failure	Do.
Do	Pepper to tomato.	do	do	C.		Success	Do.
Do	Tomato	do	Surface	C.		Failure	Do.
Do	Quince	do	Puncture	C.		Success	Halsted, 1892.
Watermelon	Apple	do		C.		Failure	Edgerton, 1908.
Do	Bean	do	Puncture	C. or H.		Success	Halsted, 1893.
Do	Citron[1]	Picked fruit.	do	do	Host	do	Do.
Do	Cucumber	Leaves	Surface	C.	do	do	Sheldon, 1904.
Do	do	Unpicked fruit.	Puncture	C.	do	do	Do.
Do	do	Picked fruit.	do	C.	Culture	do	Do.
Do	Gourd	Seedling	Surface	C.	do	do	Do.
Do	Muskmelon	Unpicked fruit.	Puncture	C.		do	Do.
Do	do	Seedling	Surface	C.	Culture	do	Do.
Do	do	do	do	C.		do	Do.
Do	Pumpkin	do	do	C.	Culture	Failure	Do.
Do	Pear	Fruit on tree	Puncture	C.		Sucess	Taubenhaus, 1911.
Do	Sweet pea	Seedling	do	C.		do	Do.
Do	do	do	Surface	C.		do	Do.
Yellow sweet clover.	Apple	Ripe fruit		C.	Pure culture	Failure	Edgerton, 1911.
Do	Fig	Green fruit		C.	Culture from stem.	Partial success.	Do.

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[1] *Citrullus vulgaris* var.

PARASITISM OF GLOMERELLA.

That Glomerella is an active parasite in certain races and under certain conditions would never be questioned by one who has had an opportunity to observe a severe attack of bitter-rot of the apple such as occurred in an orchard near Vienna, Va., in 1911. Several trees of Willow Twig apples well cared for and in a thrifty condition and bearing a good crop of fruit were attacked in July when the fruit was about half grown. Within a week or two nearly every apple on these trees showed bitter-rot spots which developed rapidly and soon destroyed the crop. This result was apparently due to a combination of favorable factors, the presence of a virulent race of the fungus, a susceptible variety of fruit (other varieties immediately adjoining showed little or no bitter-rot), and optimum conditions of temperature and moisture for infection and development.

Many races of Glomerella under ordinary conditions appear to be rather weak parasites. The different degrees and manifestations of parasitism among the fungi are so numerous and varied that it is very difficult to classify them satisfactorily in this respect. The possession of dormant hibernating hyphæ which infest the seeds of some annual plants, as in the case of the cotton and bean anthracnoses, the shoots of perennials, as in orange, and the leaves of evergreens, as in the case of the rubber plant, coffee, tea, citrus fruits, and other subtropical plants, indicates a considerable degree of specialization which would appear to give Glomerella a higher rank among parasites than the Fusarium forms of Nectria and closely related organisms. On the other hand, its ready growth on artificial culture media, dead organic matter and matured fruits suggests a low form of parasitism. As already mentioned, Appel and Wollenweber (1) have suggested that the fact that an organism will complete its life history on artificial culture media or dead organic matter is an indication that it is a saprophyte. As has already been pointed out, this suggestion does not seem to accord with the known facts.

The majority of the inoculation experiments which have been reported were performed by puncture of mature or nearly mature fruits. This method does not furnish the best proof of the parasitism of the organism. It is quite possible that the fungus would grow and develop rot under such conditions but still might not under natural conditions be able to gain entrance through the unbroken surface of the fruits.

The experiments of Edgerton (28), Rolfs (66), Barre (7, 8), Hasselbring (45), Bessey (13) and others, as well as some of those of the present writers, have shown that cross-inoculations can be successfully made by the application of spores to the uninjured stems, leaves, and flowers of living plants. Hasselbring (45) has shown a way in which the appressoria, or chlamydospores, assist the fungus in gaining entrance to the tissues of the host. In the majority of cases the most probable explanation of the dormant infections which have been shown to be present in so many instances in leaves and fruit showing no external evidence of disease, is that the conidia or ascospores germinate whenever they come in contact with the plant surface under favorable conditions of temperature and moisture and produce appressoria, which are able to endure more unfavorable conditions than the spores and which in turn send a germ tube through the epidermis. This tube apparently penetrates at first but a very short distance and does little harm to the host cells, remaining in a dormant or inactive condition until the host becomes weakened or injured or the organ infected dies a natural death. Bodies resembling appressoria have been found on the surface of normal apple leaves upon which the fungus developed in a moist chamber and they are sometimes found in abundance on the surface of lemons and other citrus fruits. It is difficult positively to identify these bodies on a leaf surface and trace the germ tube in the tissue, and the writers have as yet been unable to devote the necessary time to this feature of the investigation to verify conclusively the suggested explanation of the facts observed.

Large series of microtome sections of presumably infected leaves, the unused portions of which developed the fungus when placed in a moist chamber, have been studied, but the presence of fungus hyphæ has not been demonstrated with certainty. This would be quite natural if the supposition that the dormant infection is restricted to a short hypha or germ tube just penetrating the surface is correct. The experiments with leaves in moist chamber, especially deciduous leaves, show that the discoloration of the tissue and the development of the fungus start at rather definite points on the leaves and spread from these in a more or less circular manner, as shown in Plate V. In the case of the citrus fruits there appears to be quite clear evidence, from the work of Rolfs (67), Bessey (12, 13), as well as from that of the writers with leaves and shoots in moist chambers that the fungus in some cases enters the stem by way of the flowers and works back through the tissue. The development of the fungus first in the petiole and along the midrib, as frequently happens in the case of orange and rubber plant leaves in moist chamber, would suggest this possibility, though in these latter cases the infection may have been localized on the petiole or midrib.

These organisms generally develop most rapidly and do most damage to nearly or quite mature fruit and have developed special methods of insuring their survival and distribution from season to season, not only by means of appressoria but by hibernating hyphæ in old fruits, leaves, and branches and by ascospores.

DIFFERENCES IN VIRILITY OF RACES FROM THE SAME HOST.

From the experiments of the writers it appears clear that there is considerable variation in the virility of different races or strains of Glomerella just as there is in their morphological characters. As mentioned in the records of inoculation experiments, conidia from cultures from different apples when inserted in the fruit showed considerable difference in the production of rot. Some of these races produced rot more slowly than those derived from other hosts. This fact increases the difficulty of developing a resistant variety of any host as a means of counteracting disease, as has been attempted with cotton and bean. Barrus (9) at first reported certain varieties of beans as entirely resistant to the anthracnose fungus with which he was working. Later he (10) found that when other strains of the fungus were used these varieties became infected with the disease. The observations of Scott (73) that the Ben Davis apple is very severely attacked by bitter-rot in Arkansas, while it is seldom seriously injured by the disease in Virginia, although other varieties in the same locality are destroyed, is also perhaps to be accounted for by the presence of strains of different virility in the two regions. A variety or race of a host may be very resistant to a certain strain of a fungus but may succumb to a more virile strain of the parasite at any time. This also accords with the results of animal pathologists as reported by Slack (82) and others in the case of pathogenic bacteria. We must not fail to recognize that the parasite is apparently capable of as great variability in every direction as the host.

METHODS OF PREVENTION AND CONTROL.

In the cases in which these diseases are known to be transmitted through the seed, as in cotton and beans, the trouble may be largely prevented by the careful selection of fungus-free seed, as shown by Barre (7) for cotton and Whetzel (95) for beans. The work of Duggar (27) and Barre (7) with cotton, Barrus (9, 10) with beans, and Bain and Essary (4) with clover seems to indicate that more or less resistant varieties may be obtained. In this connection it should be constantly borne in mind, as already stated, that the fungous parasite is an organism evidently subject to the same laws and possesses the same or possibly greater capacity for variation, not only in form but in virility, as its host plants. This has been demonstrated by the writers' work, as indicated elsewhere in this paper, and is confirmed by the experience of Barrus (10) and others. Sanitary measures and eradication methods will prove helpful. Cutting out and destruction of cankers where they occur, the destruction or burying through cultivation of mummied fruits and infested leaves, should be practiced wherever practicable.

Spraying is, however, the most important general method of preventing disease caused by Glomerella. The work of Scott (73) and others with the bitter-rot of apples has shown that the proper application of Bordeaux mixture will largely protect fruit from this disease. Rolfs (66) has shown that the wither tip of citrus fruits, due to Glomerella, can also be controlled by spraying. There is no reason to doubt that diseases of other plants caused by the same fungus can be largely prevented by the proper use of Bordeaux mixture. In determining dates for spraying it is important to first discover the natural infection periods and to spray the plants before infection occurs. As has already been indicated, a considerable part of the infection is brought about by the appressoria or chlamydospores. The germ tube from an appressorium having penetrated the epidermis of the host is apparently beyond the reach of injury by a fungicide; and this infection, though it may remain dormant more or less indefinitely under certain conditions, may also develop and cause serious injury under certain other conditions. The time and method of infection apparently varies in many cases, depending upon conditions which favor the production, dissemination, and germination of the spores.

SUMMARY.

(1) Most cultivated fruits and many other economic plants are attacked and seriously injured by fungous parasites of the genus Glomerella.

(2) These fungi pass through three stages in the course of their complete development and produce three kinds of spores—conidia, ascospores, and chlamydospores or appressoria. Until recently the two principal spore forms, conidia and ascospores, have been described and treated as distinct organisms.

(3) The conidial stage is most frequently observed and described, and is usually referred to one or the other of the form genera Gloeosporium and Colletotrichum. About 500 so-called species of conidial forms probably belonging to Glomerella are recorded.

(4) The genetic connection of the conidial with the ascogenous stage was first definitely proven with cultures in 1898 by Atkinson, working with *Glomerella* (*Gloeosporium*) *cingulata* (Stonem.) S. and v. S. found on privet. Since that date the life-history forms, races, and species of the organism from several other host plants has been recorded by Clinton, Stoneman, Edgerton, Sheldon, Koorders, and the present writers.

(5) The life histories of forms from 36 different host plants have been determined and recorded here. In 17 cases they were produced in pure cultures and in the other 19 cases they developed on the host either in a moist chamber or under natural conditions. In 31 cases they were first reported by the writers.

(6) In most of the forms studied neither morphological nor physiological differences sufficient for the segregation of species have been found. All the material from the 36 hosts is referred to three species of *Glomerella*, G. *cingulata*, which occurs on 34 of the hosts, G. *gossypii* on one, and G. *lindemuthianum* on one.

(7) *Glomerella cingulata* is exceedingly variable in all its characters so far as they have been studied. The cause of this variability is not yet clear. No constant or definite relation has been established between the cultural and other environmental conditions and the most important variations observed.

(8) The fungus is found to be present in many cases in apparently normal and healthy foliage, fruits, and sometimes in the stems of its hosts, as shown by its development and fructification on such portions of plants after they have been thoroughly washed in a corrosive-sublimate solution which has been shown to kill not only ascospores and conidia but also the chlamydospores or appressoria of the fungus. The chlamydospores or appressoria evidently send a germ tube through the epidermis of the host as shown by Hasselbring, and this remains in a quiescent condition until opportunity for further development occurs.

(9) Inoculation experiments with fruits have shown that most of the forms from different hosts will produce the characteristic Glomerella rot on fruits of other hosts. It is also shown that there is great variability in the virility of different races or strains of the fungus from the same host. In one experiment races from the lemon, grape, and fig produced more serious cases of bitter-rot of apple than a race of the fungus derived from apples. These facts are of great importance in connection with the selection and production of disease-resistant varieties of plants.

(10) The production or nonproduction of the perithecial stage of Glomerella appears to be a fairly well-fixed hereditary race character. Where a race of the fungus has been obtained by repeated trial of spores from different sources and races which develops both conidial and ascogenous fructifications in cultures it continues to produce them for many generations. An ascogenous race from Persea was grown for 23 generations from conidia. The last generation produced perithecia about as abundantly as the first. No evidence has been obtained to indicate that the production of perithecia is controlled by any of the ordinary conditions of nutriment or environment.

(11) Glomerella is a parasite which has apparently developed special features, the most important of which is its method of infection by means of chlamydospores, or appressoria, and its ability to remain in a dormant or quiescent condition until the host plant becomes weakened or injured in some way or until specially favorable

conditions for the growth of the fungus occur. In many cases the fungus never develops further until the infected portion of the host dies. The development of the fungus in seeds as in the case of cotton and bean is also evidently a special feature of Glomerella to insure its passing the winter and reaching the new crop. In nature the perithecial form, as in the case of many other pyrenomycetes, develops normally only after the death of the host tissues.

(12) The experiments of Scott, Rolfs, and others have shown that the diseases of apples and citrus fruits caused by Glomerella can be satisfactorily controlled by spraying with Bordeaux mixture. It is probable that this method can be successfully used in the prevention of the diseases of other plants caused by this fungus. The selection of fungus-free seed is also an effective method of reducing loss from disease, as shown by Barre for cotton and Whetzel for beans. Eradication and destruction of dead and diseased parts of infected plants are also important. The selection and breeding of resistant varieties may also be practicable in some cases, as indicated by the work of Bain and Essary with clover.

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EXPLANATION OF PLATES.

[Plates I, II, and III are from photomicrographs made by Mr. Lon A. Hawkins, of the Office of Fruit-Disease Investigations. All asci are magnified 450 diameters and the separate ascospores 700 diameters.]

Plate I. Figs. 1 to 15.—Photomicrographs of asci and ascospores of Glomerella, from various hosts. Fig. 1.—From grape. An ascus from a glycerin mount stained in eosin, from dried corn-meal culture 325d. Fig. 1a.—From grape. Ascospores from a fresh glycerin mount, unstained, from corn-meal agar culture 1373b. Fig. 2.—From grape. An ascus from a fresh glycerin mount stained in gentian violet, from a corn-meal agar culture 1238h. Fig. 2a.—From grape. Ascospores from same culture as figure 2. Fig. 3.—From apple. An ascus from a fresh glycerin mount stained in eosin, from a dried specimen on fruit. Fig. 3a.—From apple. Ascospores from same source as figure 3. Fig. 4.—From cranberry. An ascus from an old mount, unstained, from culture 756 from skin and pulp of New Jersey berry. Fig. 4a.—From cranberry. Ascospores from same mount as figure 4. Fig. 5.—From black raspberry. An ascus from a 2-year-old formalin mount, unstained, from plate culture from canes from Shelbyville, Tenn. Fig. 5a.—Ascospores from the same mount as figure 5. Fig. 6.—From pomelo. An ascus from a formalin mount 2 years old, unstained, from a leaf from a greenhouse of the Department of Agriculture, kept in a moist chamber. Fig. 6a.—Ascospores from the same mount as figure 6. Fig. 7.—From lemon. An ascus from a mercuric chlorid mount 1 year old, unstained, from a leaf from the Department greenhouse, kept in a moist chamber. Fig. 7a.—Ascospores from the same mount as figure 7. Fig. 8.—From orange. An ascus from a glycerin mount, stained with eosin, from a leaf from the Department greenhouse, kept in a moist chamber. Fig. 8a.—Ascospores from the same mount as figure 8. Fig. 9.—From guava. An ascus from a fresh glycerin mount from dried specimen, unstained, from a leaf from the Department greenhouse, kept in a moist chamber. Fig. 9a.—Ascospores from a fresh glycerin mount from a dried specimen, stained in eosin, from a leaf from the department greenhouse, kept in a moist chamber. Fig. 10.—From avocado. An ascus from a mercuric chlorid mount 1 year old, unstained, from leaves from the Department greenhouse, kept in a moist chamber. Fig. 10a.—Ascospores from the same mount as figure 10. Fig. 11.—From loquat. An ascus from a glycerin mount, stained with eosin, from a leaf from the Department greenhouse, kept in a moist chamber. Fig. 11a.—Ascospores from the same mount as figure 11. Fig. 12.—From cotton. An ascus from an old slide, unstained, from a culture. Fig. 12a.—Ascospores from the same slide as figure 12. Fig. 13.—From bean. An ascus from an old formalin mount, unstained, from corn-meal culture 485a, from bean pods from Takoma Park, Md. Fig. 13a.—Ascospores from corn-meal culture 484 from same source as figure 13. Fig. 14.—From coffee. An ascus from a fresh glycerin mount from a dried specimen, stained in eosin, from a leaf from the Department greenhouse, kept in a moist chamber. Fig. 14a.—Ascospores from a fresh glycerin mount, stained in eosin, from a leaf from the Department greenhouse, kept in a moist chamber. Fig. 15.—From camellia. An ascus from a fresh glycerin mount from a dried specimen, unstained, from a leaf from the Department greenhouse, kept in a moist chamber. Fig. 15a.—Ascospores from a fresh glycerin mount from a dried specimen, unstained, from a leaf from the Department greenhouse, kept in a moist chamber.

Plate II. Figs. 16 to 29.—Photomicrographs of asci and ascospores of Glomerella from various hosts. Fig. 16.—From tea. An ascus from a fresh glycerin mount, stained in eosin, from leaves from the Department greenhouse, kept in a moist chamber. Fig. 16a.—Ascospores from an unstained glycerin mount from the same material as figure 16. Fig. 17.—From privet. An ascus from a 2-year-old formalin mount, unstained, from twigs from Digby, Nova Scotia. Fig. 17a.—Ascospores from same mount as figure 17. Fig. 18.—From rubber plant. An ascus from a glycerin mount from fresh specimen, stained, from leaves from the Department greenhouse, kept in a moist chamber. Fig. 18a.—Ascospores from a glycerin mount, stained in eosin, from the same source as figure 18. Fig. 19.—From *Ficus longifolia*. An ascus from a 1-year-old formalin mount, unstained, from leaves from the Department greenhouse, kept in a moist chamber. Fig. 19a.—Ascospores from same mount as figure 19.—Figure 20.—From honey locust. An ascus from an old mount, probably formalin, unstained, from corn-meal culture from leaves from the grounds of the Department of Agriculture. Fig. 20a.—Ascospores from same mount as figure 20. Fig. 21.—From spiral flag (*Costus speciosa*). An ascus from a fresh glycerin mount from dried specimen, stained in eosin, from a leaf from the Department greenhouse, kept in a moist chamber. Fig. 21a.—Ascospores from a 2-year-old formalin mount, unstained, from the same specimen as figure 21.—Fig. 22.—From *Curculigo* sp. An ascus from a formalin mount, 1 year old, slightly stained in methyl blue, from a leaf from the Department greenhouse, kept in a moist chamber. Fig. 22a.—Ascospores from the same mount as figure 22. Fig. 23.—From ebony (Brya). An ascus from a glycerin mount from a fresh specimen, stained in eosin, from a leaf from the Department greenhouse, kept in a moist chamber. Fig. 23a.—Ascospores from the same mount as figure 23. Fig. 24.—From chocolate (*Theobroma cacao* L.) An ascus from a glycerin mount from fresh material, stained in eosin, from a leaf from the Department greenhouse, kept in a moist chamber. Fig. 24a.—Ascospores from the same mount as figure 24. Fig. 25.—From Pitcairnia. An ascus from a fresh glycerin mount from dried specimen, stained in eosin, from a leaf from the Department greenhouse, kept in a moist chamber. Fig. 25a.—Ascospores from a glycerin mount, stained in eosin, from the same material as figure 25. Fig. 26.—From palm (*Hedyscepe* sp.). An ascus from an old mount, probably in formalin, unstained, from a leaf from the Department greenhouse. Fig. 26a.—Ascospores from a fresh glycerin mount, stained with eosin, from a leaf from the Department greenhouse. Fig. 27.—From ginkgo. An ascus from an old mount, probably in formalin, unstained, from a leaf from the grounds of the Department of Agriculture. Fig. 27a.—Ascospores from the same mount as figure 27. Fig. 28.—From Caryota. An ascus from a mercuric chlorid mount, 1 year old, unstained, from a leaf from the Department greenhouse, kept in a moist chamber. Fig. 28a.—Ascospores from the same slide as figure 28. Fig. 29.—From fig. An ascus from a fresh glycerin mount, unstained, from corn-meal agar culture 1283d from conidia on fruit from Norfolk, Va. Fig. 29a.—Ascospores from the same mount as figure 29.

Plate III. *Glomerella cingulata*.—Three series of asci from different hosts, showing the wide range of variation observed. Photomicrographs from fresh glycerin mounts. Figs. 30 to 34.—From grape. All from cultures of the same origin. Fig. 30.—An ascus 101 μ long, from corn-meal agar slant culture 1373b from Vienna, Va. Fig. 31.—An ascus 87 μ long, from the same culture. Fig. 32.—An ascus 77.5 μ long, from the same culture. Fig. 33.—An ascus 70.5 μ long, from another tube from the same source. Fig. 34.—An ascus 54.5 μ long, from corn-meal agar culture 1373b. Figs. 35 to 39.—*Glomerella cingulata* from apple. Fig. 35.—An ascus 108 μ long, from corn-meal agar slant culture 1348k, from conidia on Willow Twig apple from Vienna, Va. Fig. 36.—An ascus 89.5 μ long, from the same culture as

figure 35. Fig. 37.—An ascus 83 μ long, from same cultures as figures 35 and 36. Fig. 38.—An ascus 77 μ long, from same culture as figures 35, 36, and 37. Fig. 39.—An ascus 55 μ long, from corn-meal agar slant culture from apple leaves from Winchester, Va.—Figs. 40 to 44.—*Glomerella cingulata* from fig. Fig. 40.—An ascus 110 μ long, from corn-meal agar slant culture 1283d, from conidia on fruit from Norfolk, Va. Fig. 41.—An ascus 92.5 μ long, from same culture as figure 40. Fig. 42.—An ascus 85.5 μ long, from corn-meal agar slant 1283a, from same source as 1283d. Fig. 43.—An ascus 63.5 μ long, from corn-meal agar slant 1283e, from same source as 1283a. Fig. 44.—An ascus 56 μ long, from same culture as figure 43.

Plate IV. Pomelo leaves showing development in moist chamber of numerous colonies of *Glomerella cingulata* on apparently healthy leaves for 9 days. The lower leaf 1 year younger than the upper. The colonies originated chiefly from the midrib.

Plate V. *Glomerella cingulata* on pomelo leaves. Figure 1 shows development of numerous scattered colonies on apparently healthy leaves in moist chamber, evidently rising from separate points of infection. Figure 2 shows small leaf 1 year younger taken from the same plant and treated in the same manner. No fungus developed, as the leaf was apparently not infected.

Plate VI. *Glomerella cingulata* on 2 orange leaves, showing the development of the fungus on apparently healthy leaves in a moist chamber and the localization of the colonies which evidently originated from separate points of infection. The rubber plant leaf at the right shows the development of the fungus from the petiole along the midrib. Acervuli first developed on the petiole, which has been removed.

Plate VII. *Glomerella lindemuthianum* from bean. Six corn-meal agar cultures started from conidia from a single acervulus, showing the uniform character of cultures of this species and the characteristic dark mycelium usually producing acervuli only.

Plate VIII. *Glomerella cingulata* from Persea. Ascospore generation 2, tube *a*, showing separate perithecia thickly covering the surface of the medium. Conidial generation 13, tubes *b* and *c*, showing chiefly acervuli. Conidial generation 14, tubes *b* and *c*, originated from generation 13, *b* and *c*, respectively, are strikingly different. Of generation 14, *b* shows chiefly acervuli and conidia and *c* chiefly perithecia, which are arranged in masses along the line where the spores were planted.

Plate IX. *Glomerella cingulata* from Persea. Conidial generation 9, tube *a*, shows numerous scattered perithecia and a few acervuli near the bottom. Conidial generation 16, tubes *b* and *c*, from which conidial generation 17, tubes *b* and *c*, were made, produced almost entirely acervuli. Of generation 17, tube *b* produced almost entirely perithecia, while *c* was practically identical with generation 16, tube *c*, showing chiefly acervuli.

Plate X. *Glomerella cingulata* from Persea. Conidial generation 17 produced from 16, tube *b*, which was almost identical with tube 4. These cultures showed rather regular intergradations from tube 1, which chiefly produced perithecia, to tube 7, which produced acervuli almost entirely. Tubes all the same age.

Plate XI. *Glomerella cingulata* from Persea. Conidial generation 17, tube *b*, showing mostly perithecia, and six subcultures from the same. All the cultures except the one at the extreme right showed a great predominance of acervuli, with but few perithecia, showing a reversion to the form in generation 16, tube *b*.

Plate XII. *Glomerella cingulata* from Persea. Showing striking variations. Conidial generation 17. Tubes *d*, *e*, *f*, and *g*, all originated from generation 16, tube *b*. Compare Plate IX. Of generation 17, tubes *d*, *e*, and *f* show mostly perithecia; *g* has perithecia at the bottom of the culture and acervuli above. Of conidial generation 19, tube *b* shows mostly acervuli, while of generation 20, tube *b* produced mostly perithecia.

Plate XIII. *Glomerella cingulata* from Persea. Seven tubes from conidial generation 17, derived from generation 16, tube *c*, which produced chiefly acervuli. These cultures all produced, chiefly perithecia which were arranged in dense, scattered black masses, instead of being separate and evenly distributed, as in most cases of the preceding generations. Compare Plate IX.

Plate XIV. *Glomerella cingulata* from Persea. Two plates poured from conidial generation 9, tube *a*. Conidia were numerous at first in both plates, but were scattered, and no conspicuous acervuli seen. Only one colony, *a*, produced distinct and conspicuous acervuli. The rest of the colonies were chiefly perithecia. Compare Plate IX, tube 9 *a*.

Plate XV. *Glomerella cingulata* from Persea. Plates 10 days old made from crushed perithecia and ascospores. The irregular, scattered, large, dark bodies, *a*, are colonies of acervuli. The other colonies are chiefly perithecia. This strain of the fungus originated from a single conidium. A greater development of perithecia is observed along lines of contact between the conidial and perithecial colonies.

Plate XVI. Willow Twig apples inoculated with conidia of *Glomerella cingulata* from 4 different hosts. Figures 1 and 2 inoculated with conidia from an apple; figures 3 and 4, from a lemon; figures 5 and 6, from grapes; figures 7 and 8, from a fig. The strain of the fungus from the apple showed less virulence in this instance than that obtained from other hosts. All were inoculated at the same time, in the same manner, and kept under the same conditions.

Plate XVII. Eight figs 13 days after inoculation with conidia of *Glomerella cingulata* obtained from a rubber plant. The four upper fruits were inoculated by puncture; the four lower by surface application. All except two of those inoculated on the surface developed the common Glomerella rot of the fig.

Plate XVIII. Watermelon inoculated with conidia of *Glomerella cingulata* obtained from guava. The decayed area is practically covered with large acervuli.

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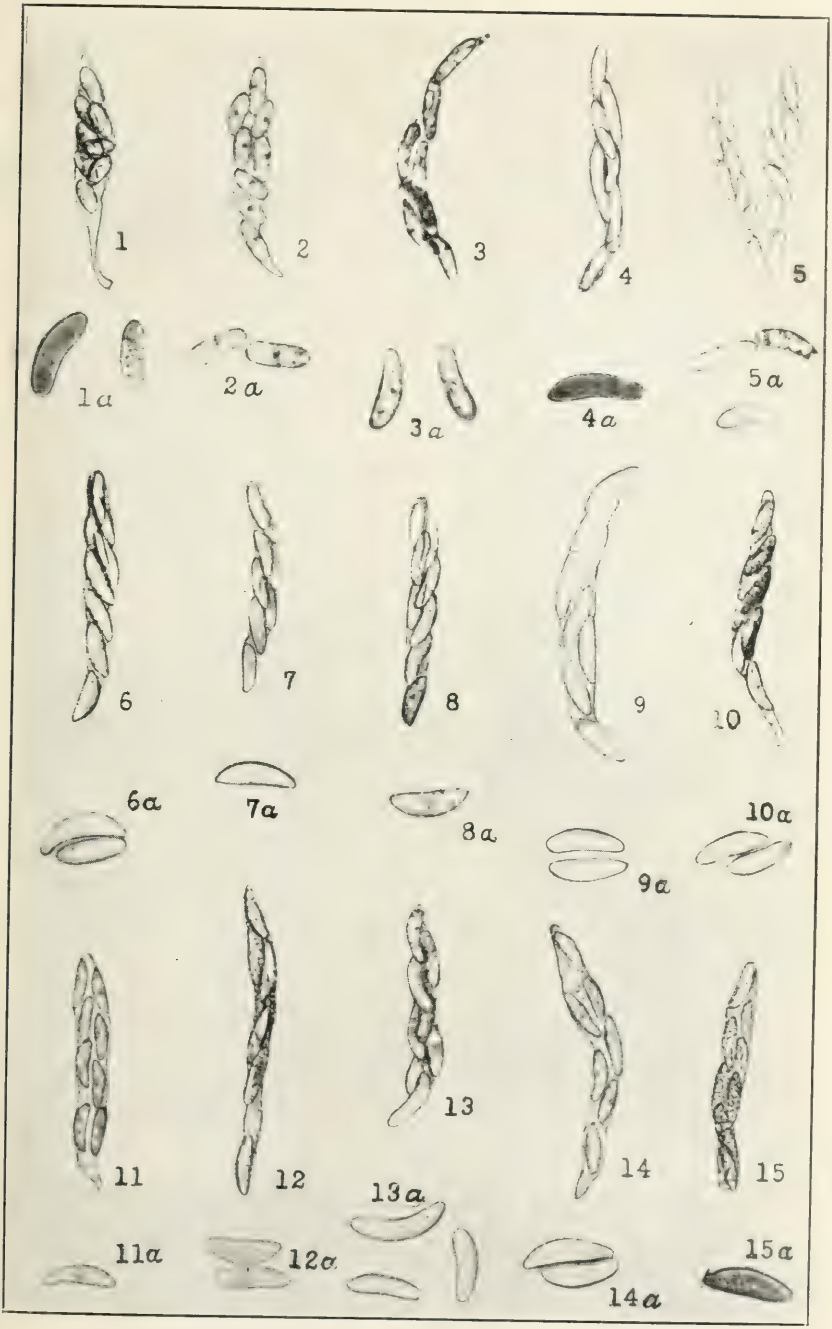
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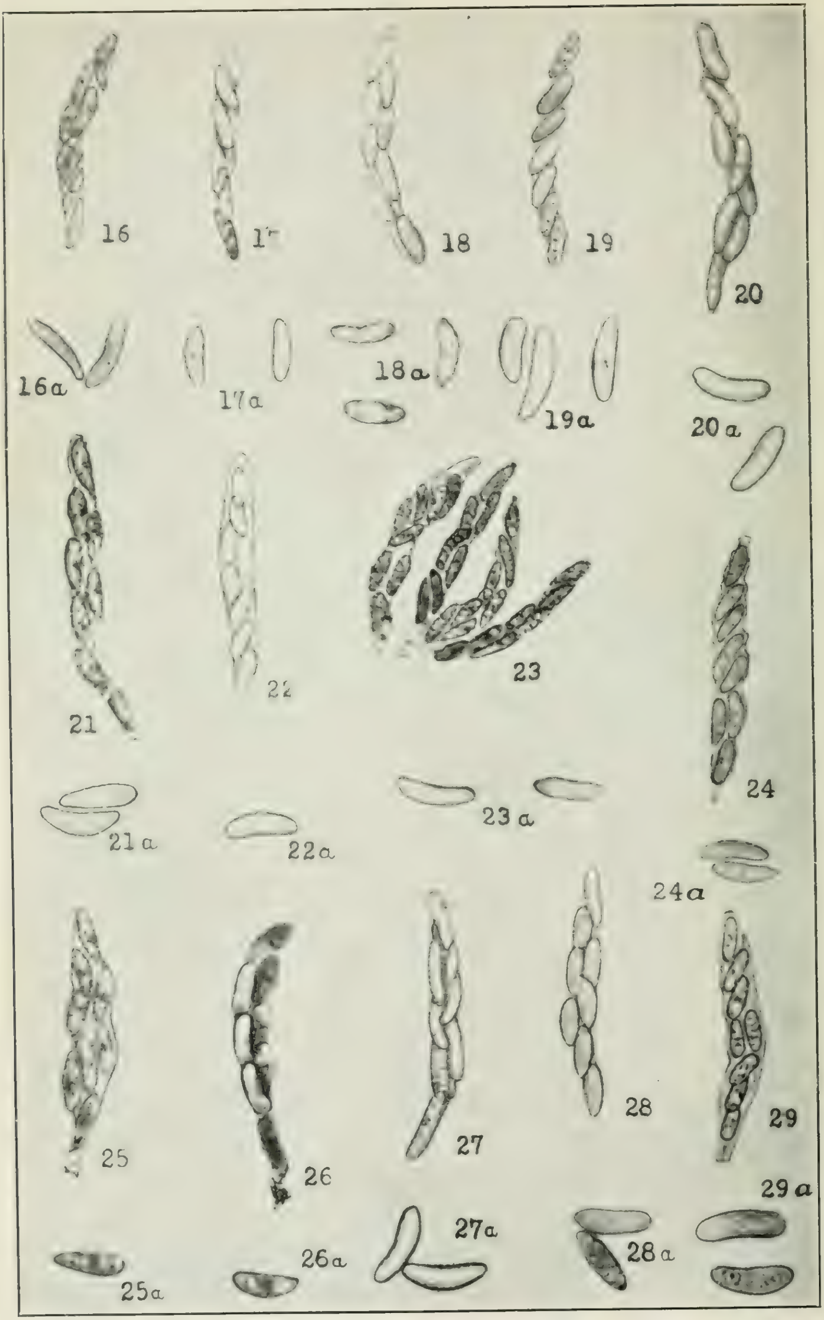
GLOMERELLA ASCI AND ASCOSPORES FROM VARIOUS HOSTS.

Figs. 1 and 2 from grape; 3, apple; 4, cranberry; 5, black raspberry; 6, pomelo; 7, lemon; 8, orange; 9, guava; 10, avocado; 11, loquat; 12, cotton; 13, bean; 14, coffee; 15, camellia. Asci × 450, separate ascospores × 700 diameters,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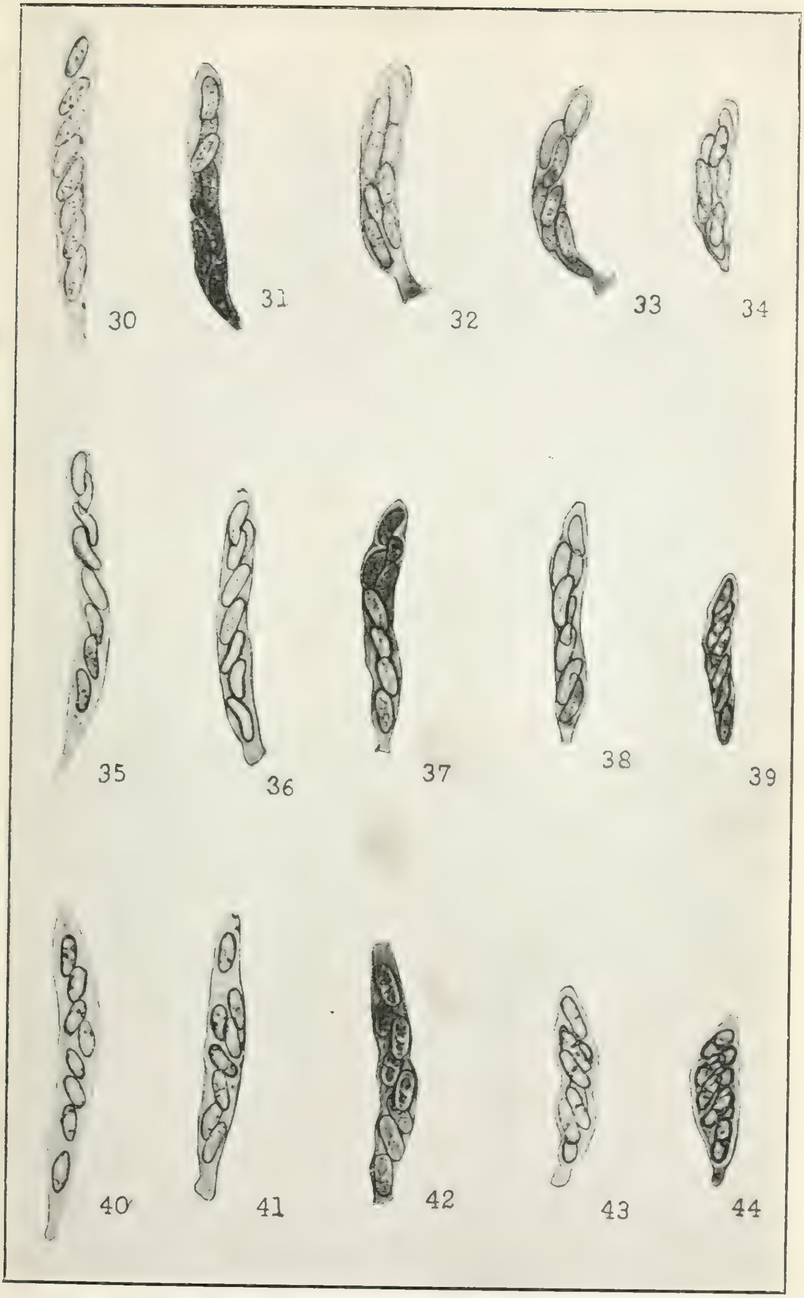
GLOMERELLA CINGULATA ASCI AND ASCOSPORES FROM DIFFERENT HOSTS.

Fig. 16 from tea; 17, privet; 18, rubber plant; 19, *Ficus longifolia;* 20, honey locust; 21, spiral flag; 22, Curculigo; 23, ebony; 24, chocolate; 25, Pitcairnia; 26, palm; 27, Ginkgo; 28, Caryota; 29, fig. Asci × 450, separate ascospores × 700 diameters.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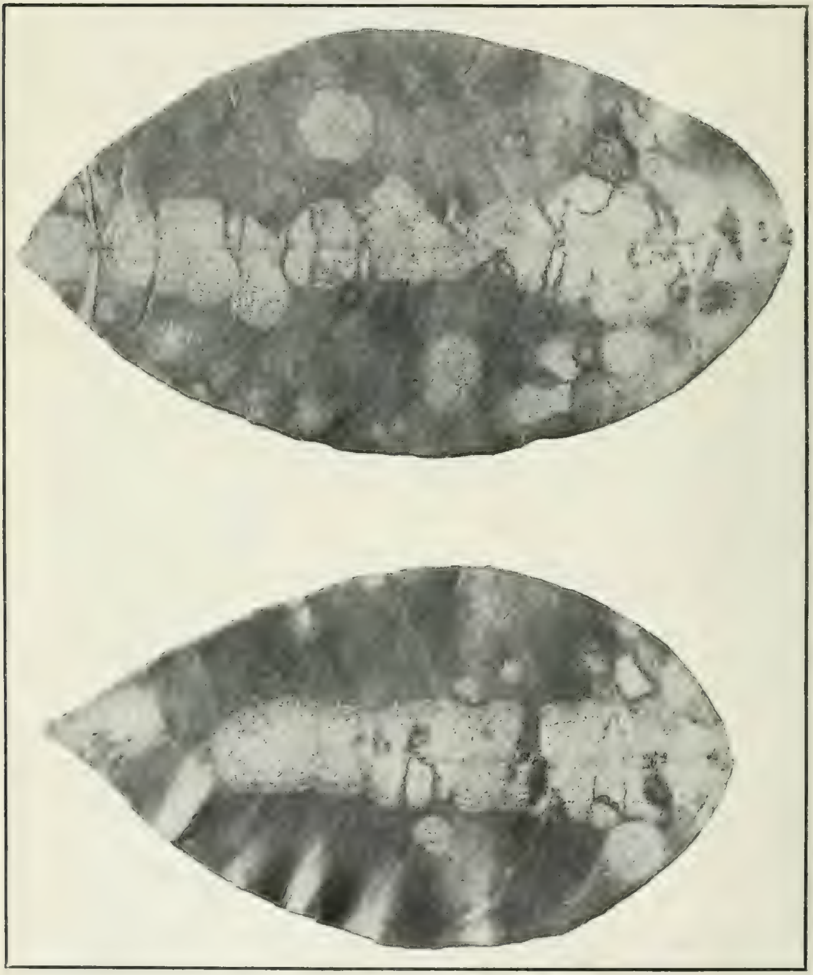
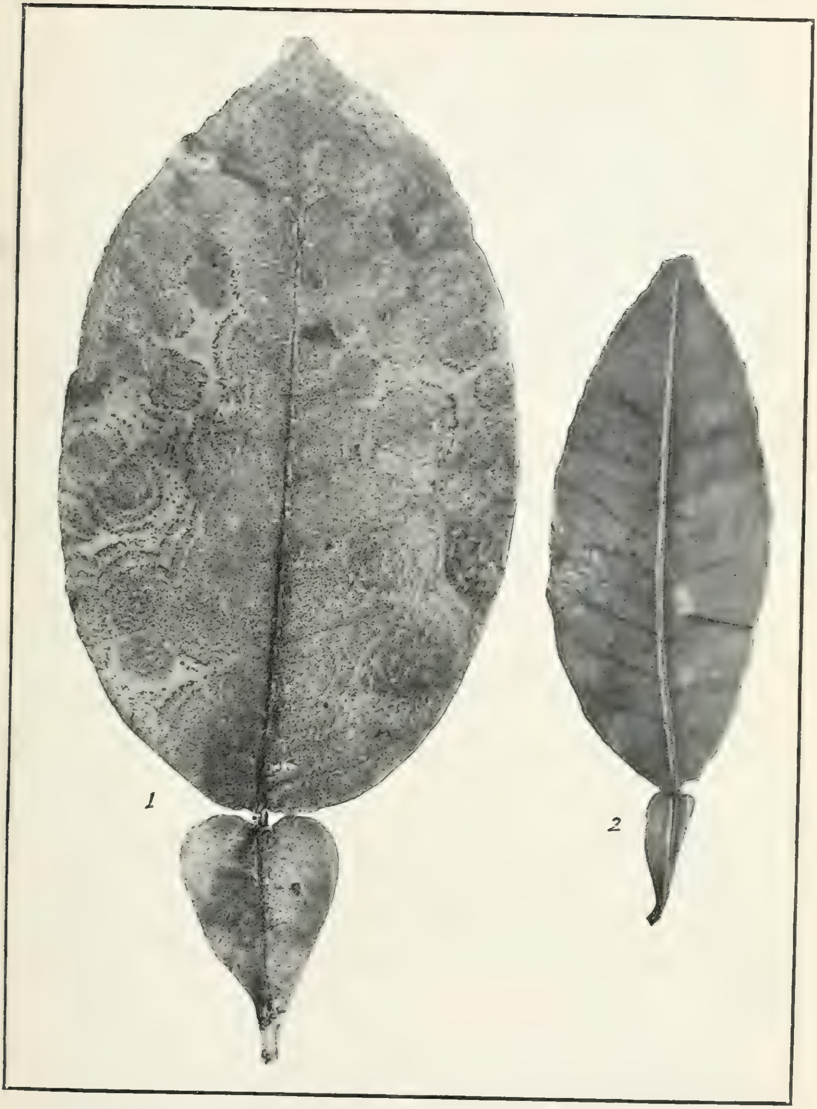
GLOMERELLA CINGULATA ASCI FROM THREE DIFFERENT HOSTS, SHOWING THE RANGE OF VARIATION IN EACH.

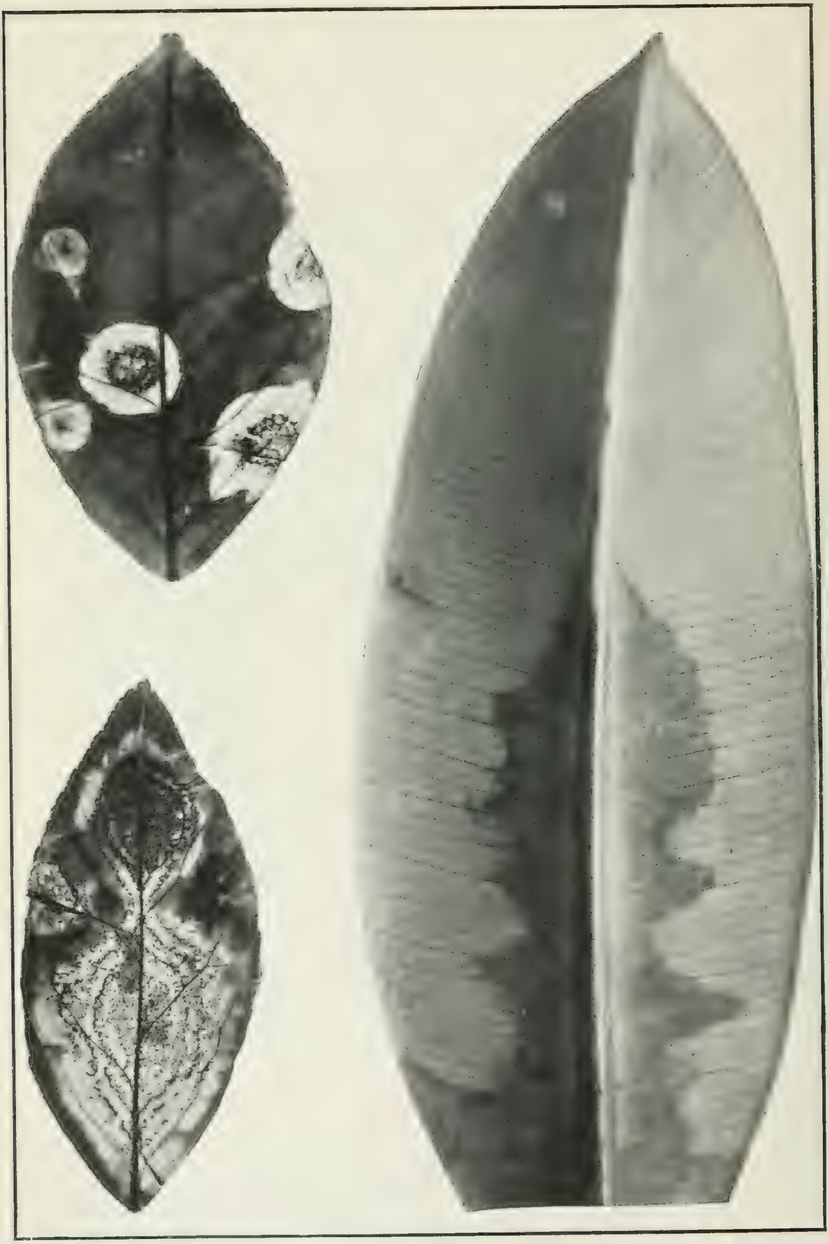
Figs. 30 to 34 from grape; 35 to 39, apple; 40 to 44, fig. All × 450 diameters.



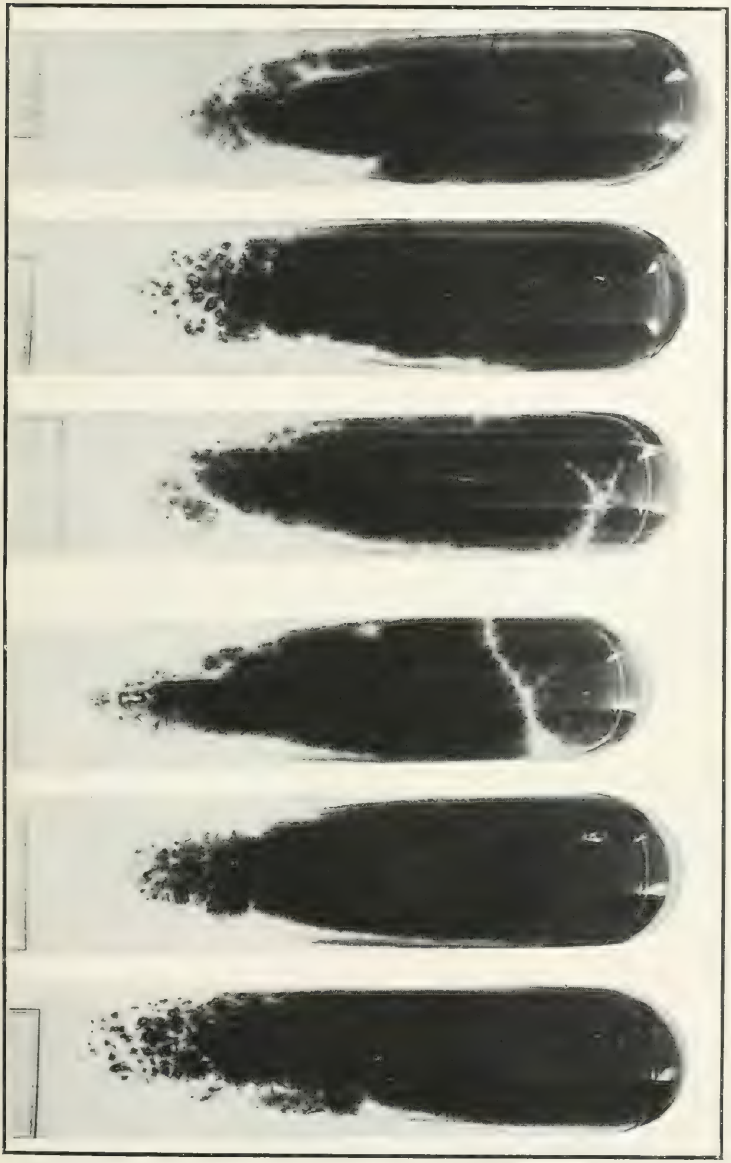
POMELO LEAVES, SHOWING DEVELOPMENT IN MOIST CHAMBER OF NUMEROUS COLONIES OF GLOMERELLA CINGULATA ON APPARENTLY HEALTHY LEAVES. ONE YEAR'S DIFFERENCE IN THE AGE OF THE LEAVES. THE COLONIES MOSTLY ORIGINATED FROM THE MIDRIB.



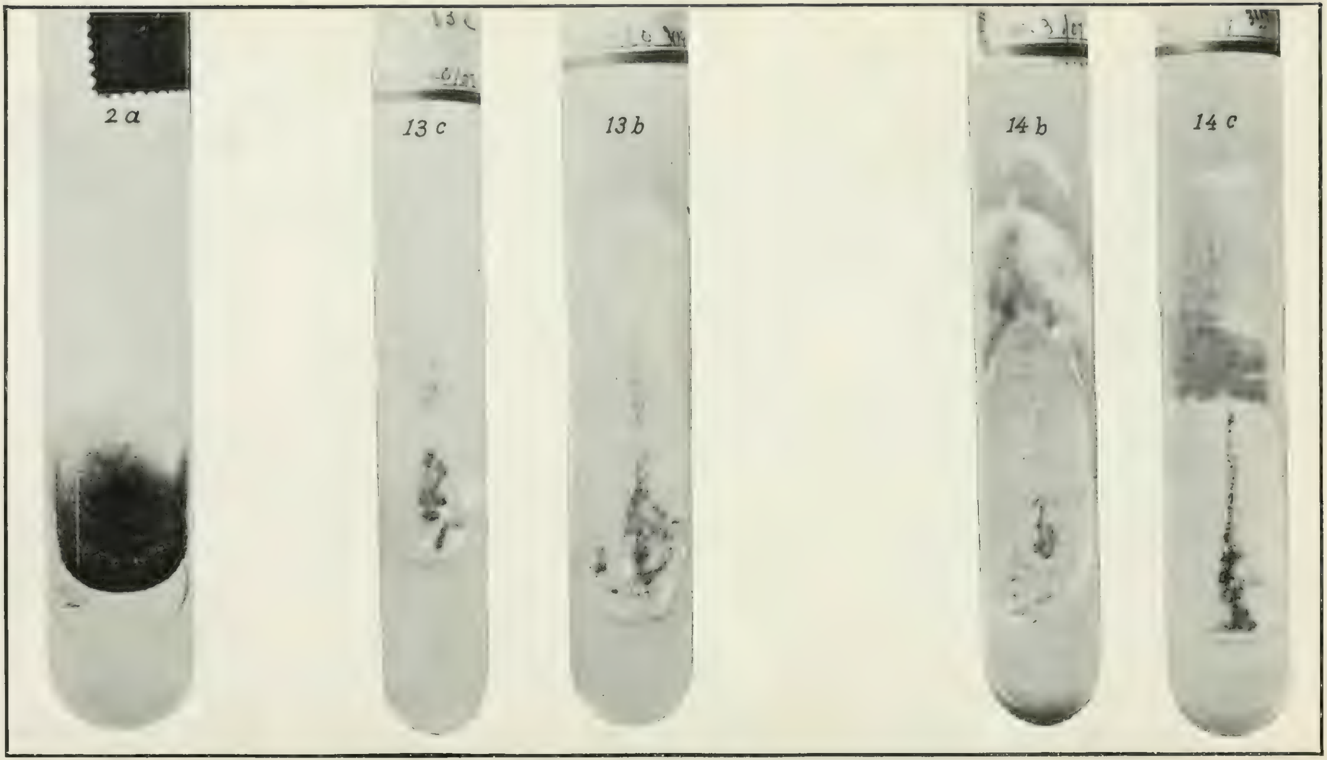
POMELO LEAVES, SHOWING (1) DEVELOPMENT OF COLONIES OF GLOMERELLA CINCULATA IN MOIST CHAMBER AND APPARENT LOCALIZATION OF NUMEROUS POINTS OF INFECTION; (2) THE SMALL LEAF ONE YEAR YOUNGER, FROM SAME PLANT TREATED IN THE SAME MANNER, APPARENTLY NOT INFECTED.



Glomerella cingulata on Two Orange Leaves, Showing Development of the Fungus on Apparently Healthy Leaves in a Moist Chamber and Localization of the Colonies. The Rubber Plant Leaf at the Right Shows Development of the Fungus Proceeding from the Petiole Along the Midrib.

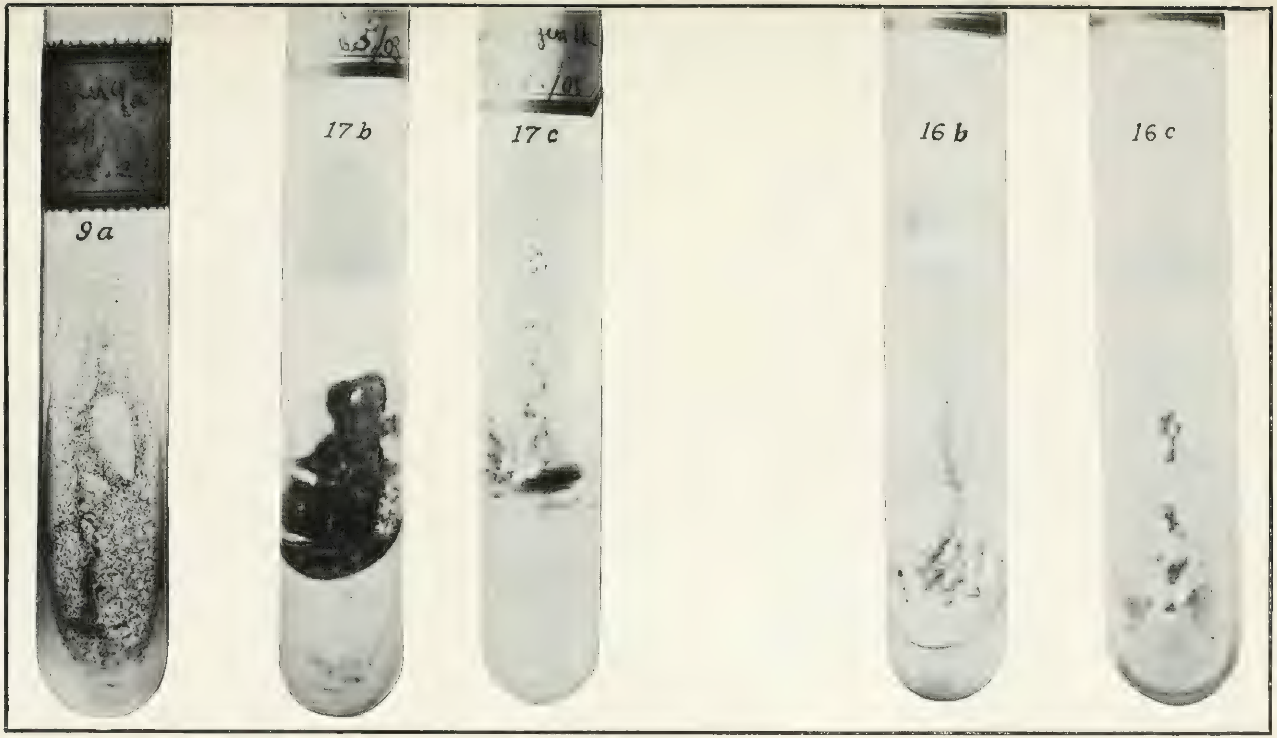


Glomerella Lindemuthianum Cultures from Bean. Six Tubes from Conidia from a Single Acervulus, Showing the Uniform Character of the Cultures and the Dark Mycelia Producing Acervuli only.



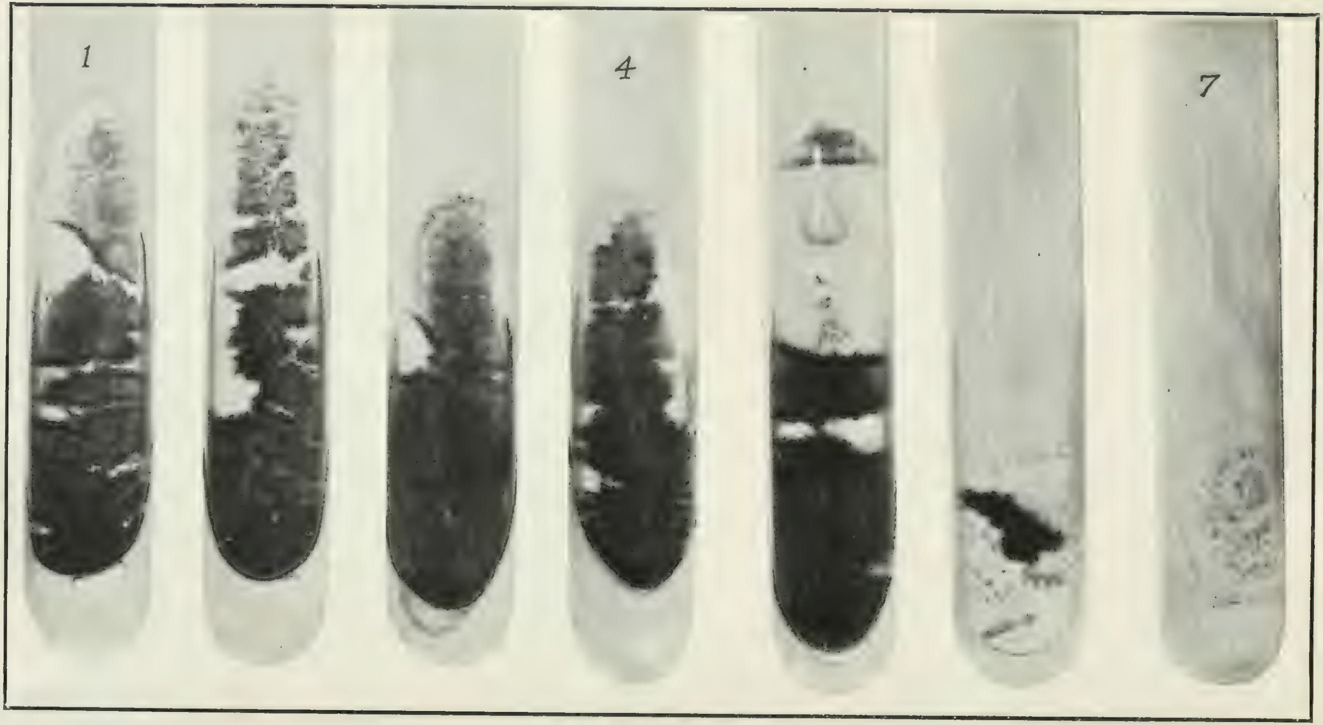
GLOMERELLA CINGULATA CULTURES FROM PERSEA—I.

Ascospore generation 2, tube *a*, showing the black perithecia thickly covering the surface. Conidial generation 13, tubes *b* and *c*, chiefly acervuli; and conidial generation 14, tubes *b* and *c*. *b* shows chiefly acervuli and conidia and *c* chiefly perithecia growing in masses along the line of inoculation.



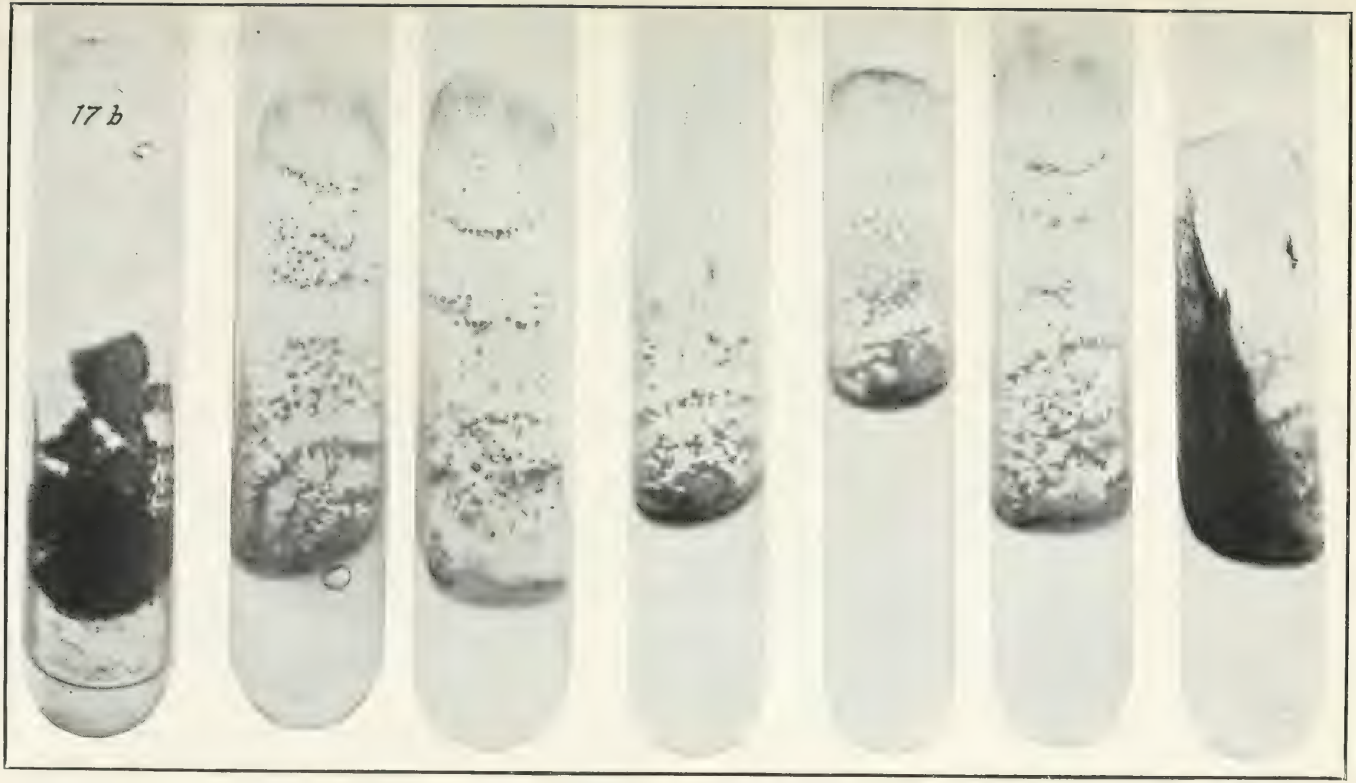
GLOMERELLA CINGULATA CULTURES FROM PERSEA—II.

Conidial generation 9, tube *a*, showing numerous perithecia and a few acervuli near the bottom. Conidial generations 16 and 17, tubes *b* and *c*. Sixteen *b* produced almost entirely acervuli; 17 *b* almost entirely perithecia, while 17 *c*, like 16 *c*, is chiefly acervuli.



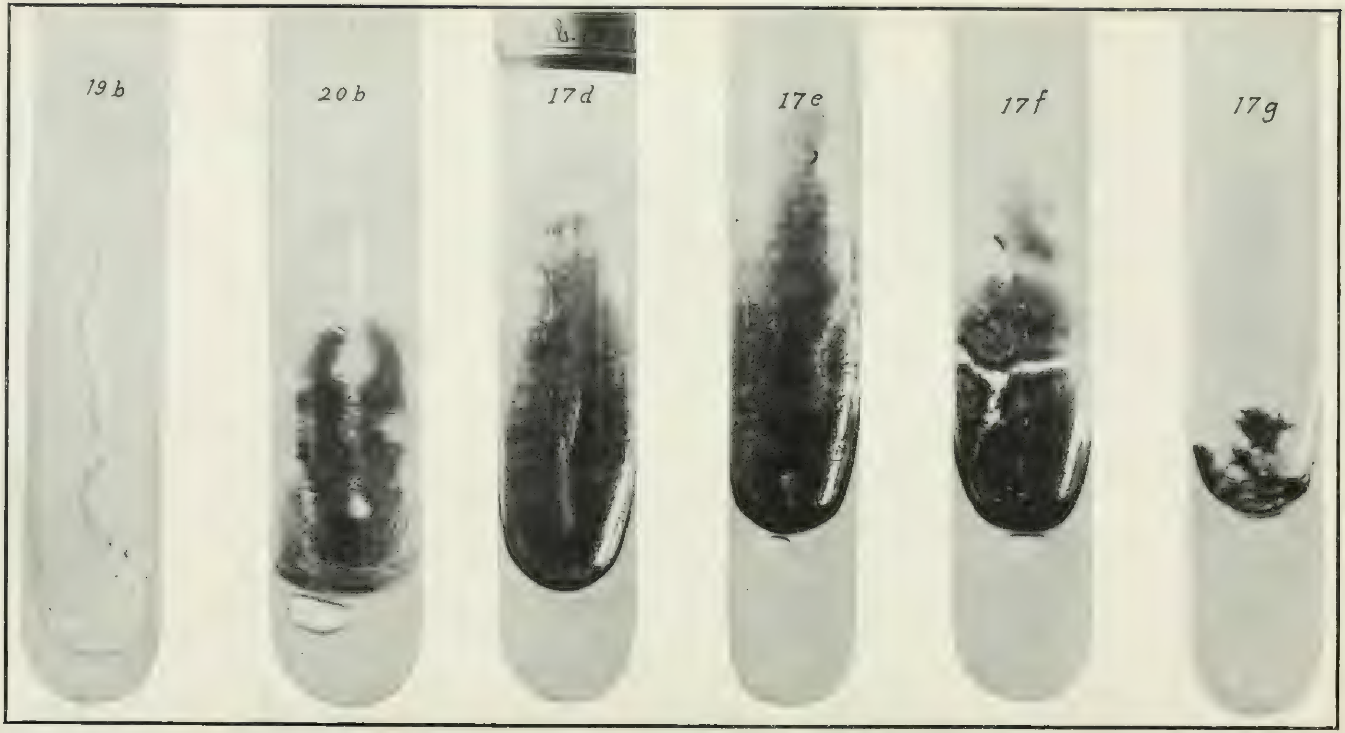
GLOMERELLA CINGULATA CULTURES FROM PERSEA—III.

Conidial generation 17, consisting of subculture from generation 16, tube *b*, showing rather regular intergradations from tube 1 containing chiefly perithecia to tube 7 containing chiefly acervuli. Compare Pl. XI.



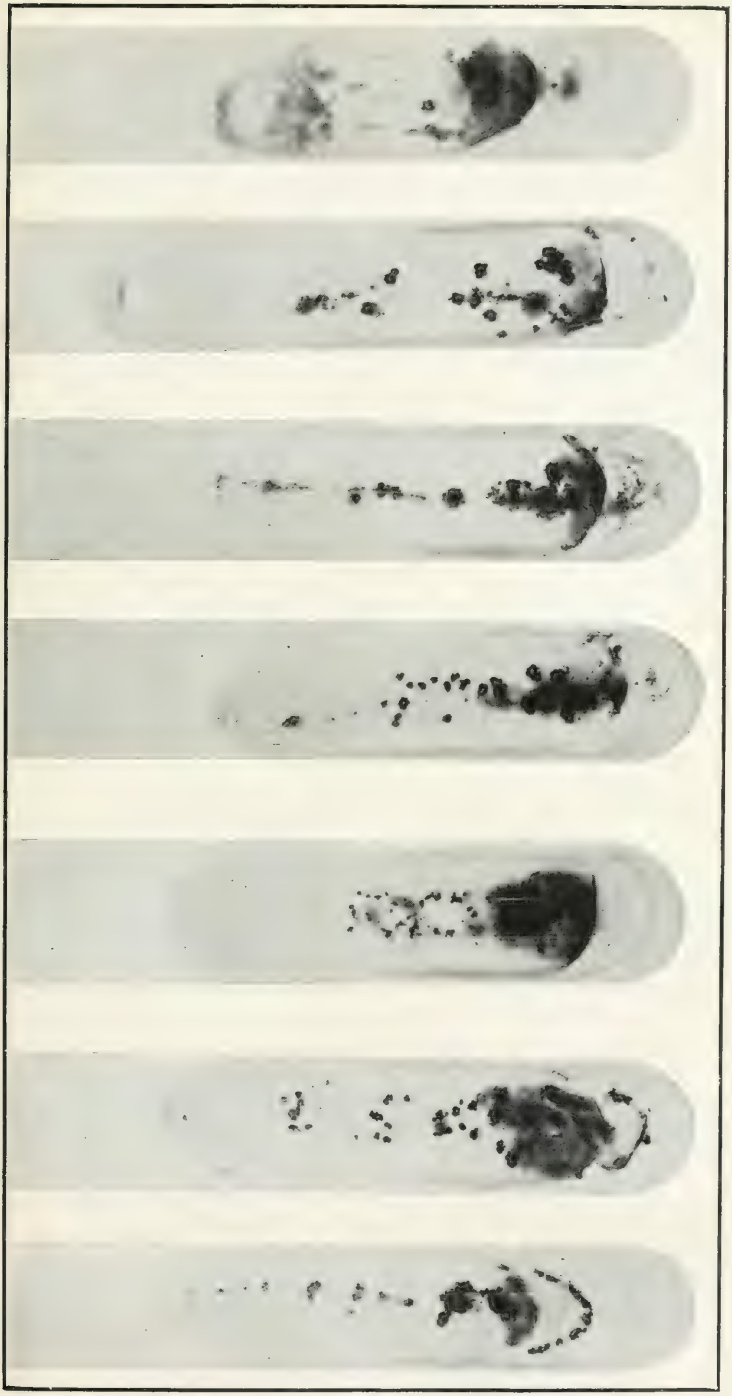
GLOMERELLA CINGULATA CULTURES FROM PERSEA—IV.

Conidial generation 17, tube *b*, showing mostly perithecia, and six subcultures from the same. These tubes, except the one at the extreme right, showed a great predominance of acervuli with few perithecia, as in 16 *b*. Compare Pl. X.



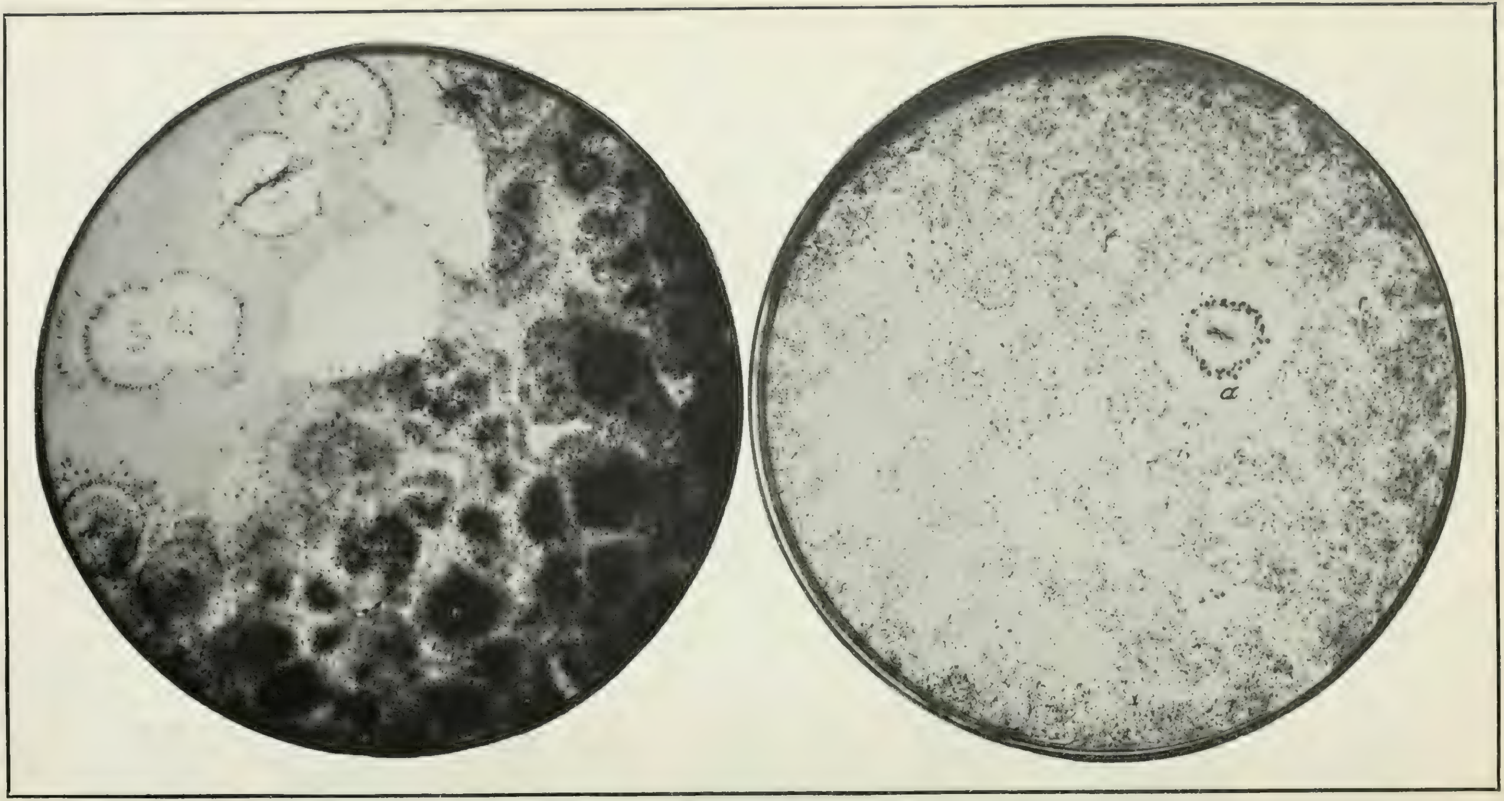
GLOMERELLA CINGULATA CULTURES FROM PERSEA—V, SHOWING STRIKING VARIATIONS.

Conidial generation 17, tubes *d*, *e*, *f*, and *g*, all from 16 *b*. Compare Plate IX. Tubes 17 *d*, *e*, and *f*, mostly perithecia; *g*, perithecia below and acervuli above. conidial generation 19, tube *b*, mostly acervuli; generation 20, tube *b*, mostly perithecia.



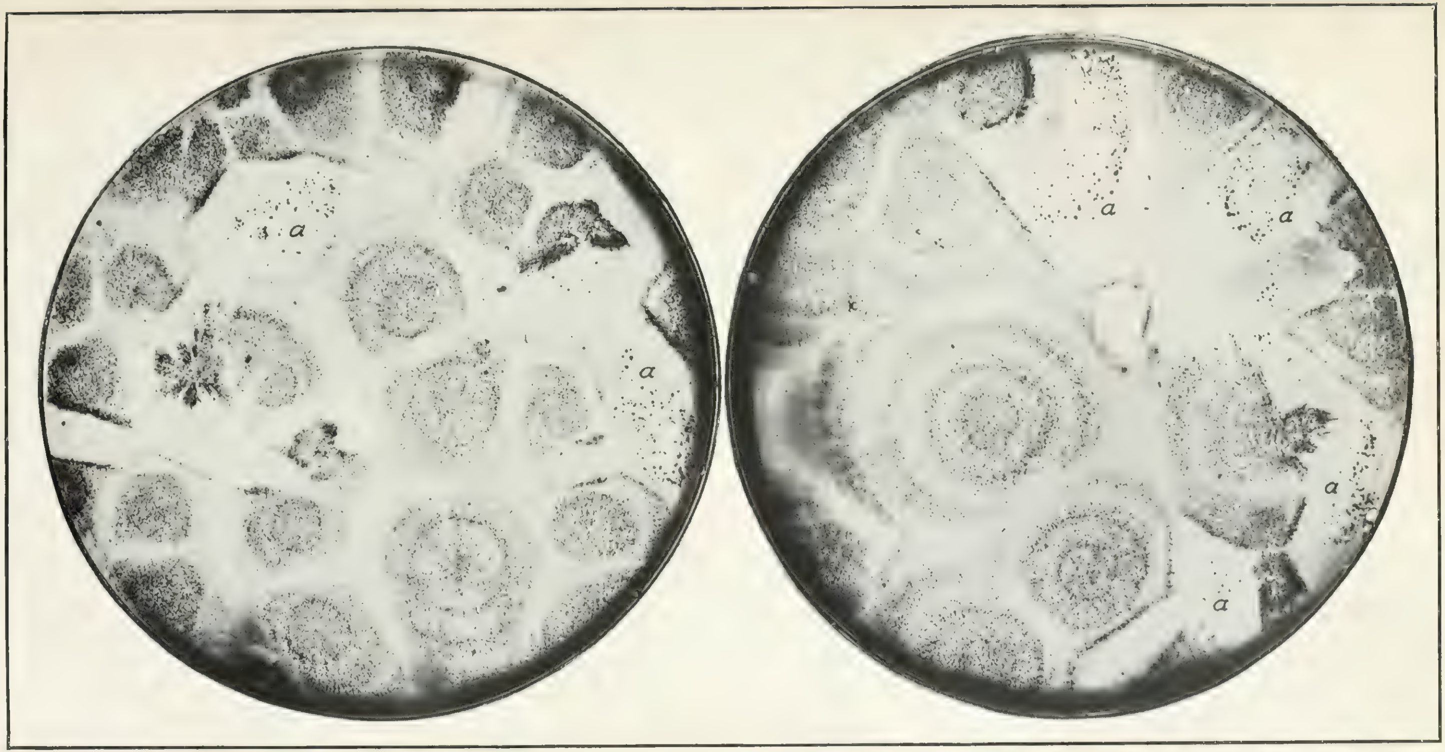
GLOMERELLA CINGULATA CULTURES FROM PERSEA—VI, SHOWING VARIATIONS.

Seven tubes of conidial generation 17, from generation 16, tube *c*, which produced chiefly acervuli. These tubes show chiefly perithecia in dark masses. Compare Pl. IX.



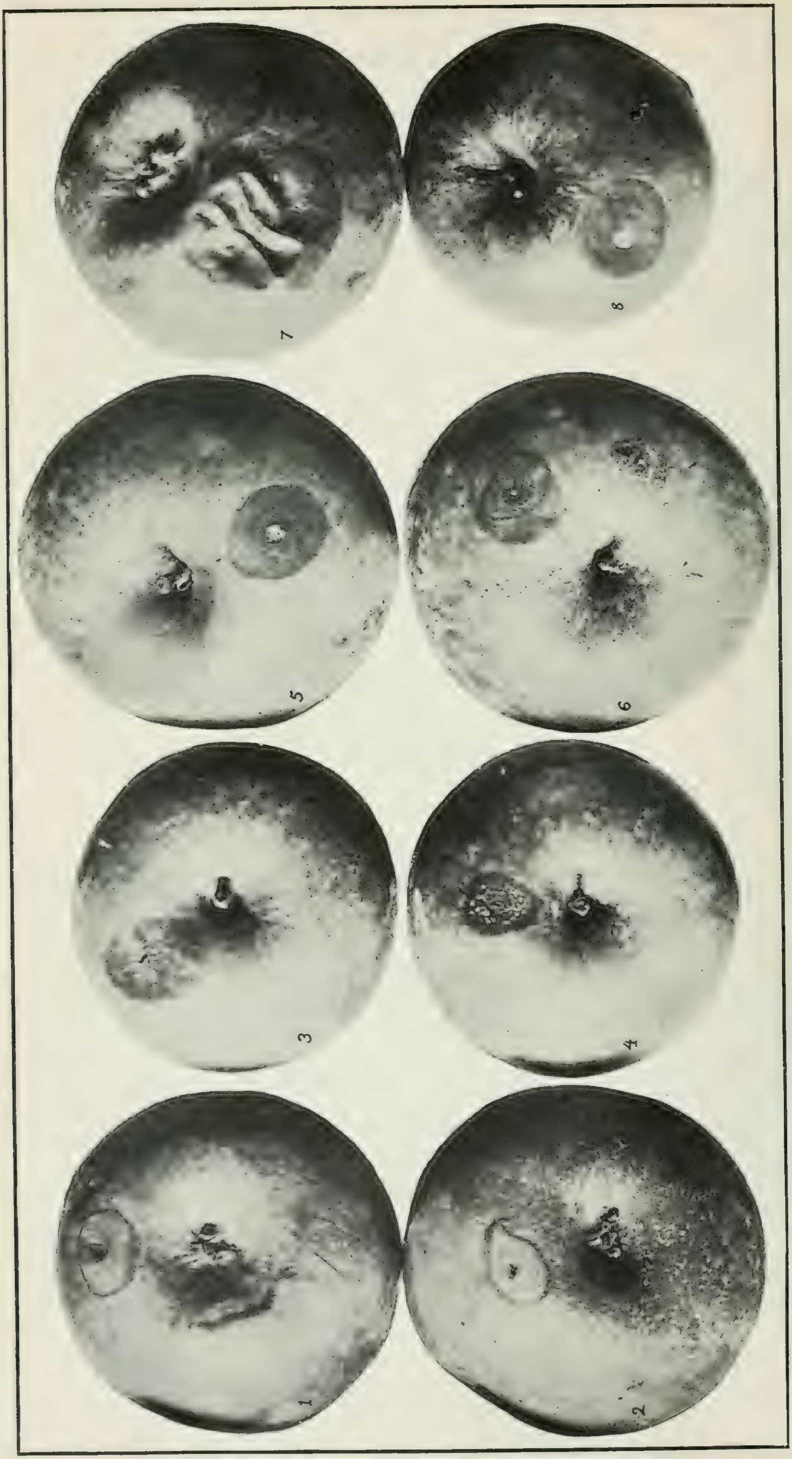
GLOMERELLA CINGULATA CULTURES FROM PERSEA—VII.

Two plates from conidial generation 9, tube *a*. Only one distinct colony, *a*, produced large acervuli, the rest chiefly perithecia. Compare Plate IX, tube 9 *a*.



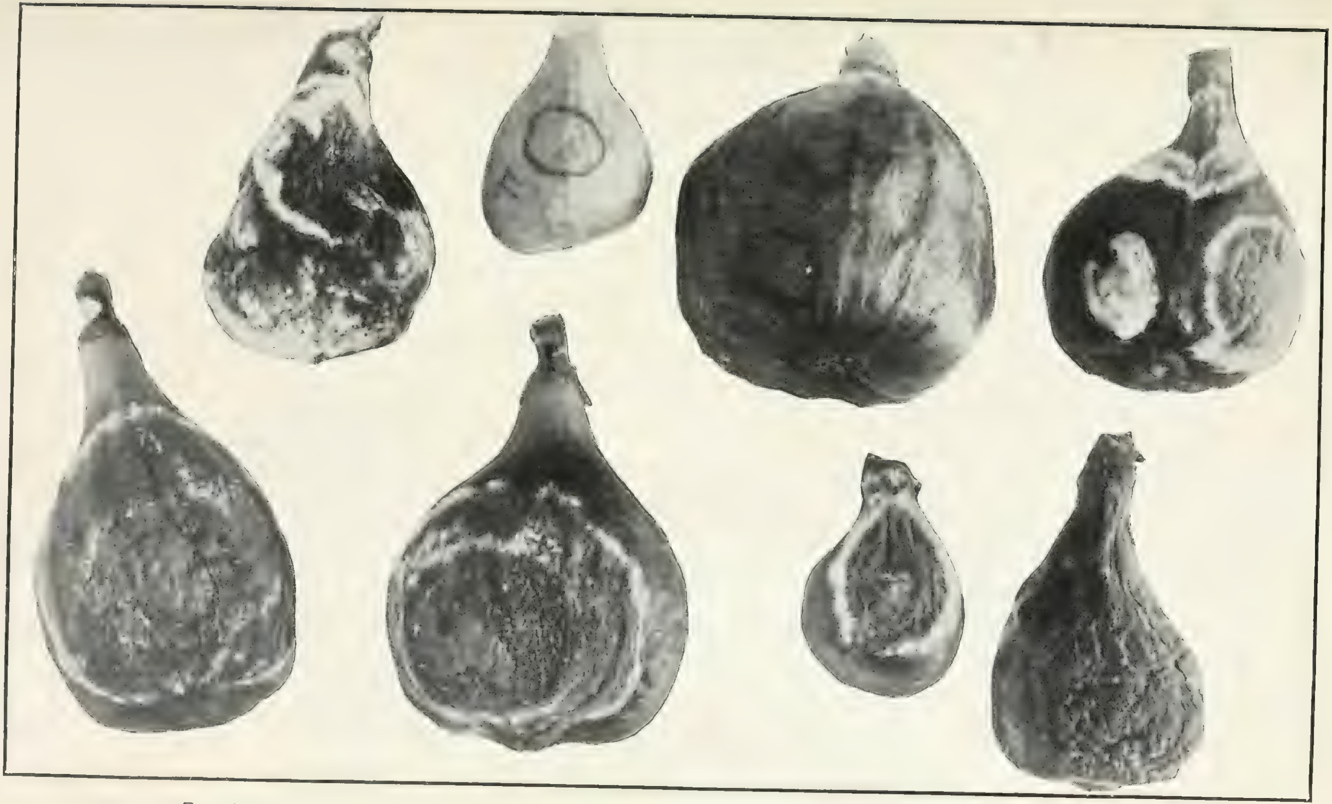
GLOMERELLA CINGULATA CULTURES FROM PERSEA—VIII. PLATES 10 DAYS OLD FROM CRUSHED PERITHECIA AND ASCOSPORES.

The irregular, scattered, large, dark spots, *a*, are colonies of acervuli, the others perithecia. Note the greater development of perithecia at the lines of contact between these colonies and the perithecial colonies.



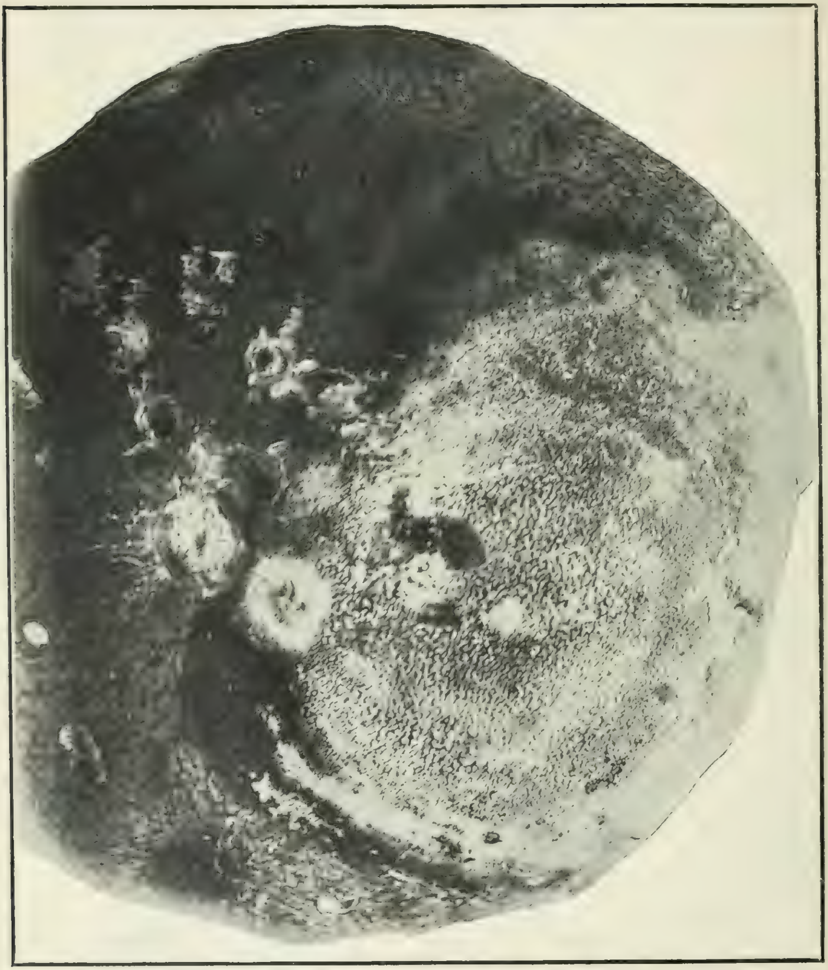
Willow Twig Apples Inoculated with Conidia of Glomerella cingulata from Different Hosts.

Figs. 1 and 2, from apple; 3 and 4, from lemon; 5 and 6, from grape; 7 and 8, from fig.



FIGS 13 DAYS AFTER INOCULATION WITH CONIDIA OF GLOMERALLA CINGULATA FROM A RUBBER PLANT.

The four upper fruits were inoculated by puncture, the four lower by surface application. All except two of those inoculated on the surface developed rot.



WATERMELON INOCULATED WITH CONIDIA OF GLOMERELLA CINGULATA FROM GUAVA. THE DECAYED AREA IS PRACTICALLY COVERED WITH LARGE ACERVULI.

Issued January 11, 1913.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 253.

B. T. GALLOWAY, *Chief of Bureau.*

THE KAOLIANGS:

A NEW GROUP OF GRAIN SORGHUMS.

BY

CARLETON R. BALL,
Agronomist in Charge of Grain-Sorghum and
Broom-Corn Investigations.

WASHINGTON:
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1913.

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[1] On July 1, 1912, the name of this office was changed from "Grain Investigations" to "Cereal Investigations."

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., April 27, 1912.

Sir: I have the honor to transmit herewith a manuscript entitled "The Kaoliangs: A New Group of Grain Sorghums," and to recommend that it be published as Bulletin No. 253 of the series of this Bureau. This bulletin was prepared by Mr. Carleton R. Ball, Agronomist in Charge of Grain-Sorghum and Broom-Corn Investigations in the Office of Grain Investigations, and has been submitted by Mr. Mark Alfred Carleton, Cerealist in Charge of Grain Investigations, with a view to its publication.

The kaoliangs comprise a new group of grain-producing sorghums from eastern Asia. During the past few years a large number of varieties and strains of this group have been introduced into the United States from China and Manchuria. Most of these introductions have been carefully tested for agronomic value in comparison with milos, kafirs, and durras. All of the varieties are drought resistant. Some of them are very early and therefore adapted to higher elevations and more northern latitudes than the members of other groups. The better sorts are now becoming distributed among farmers and it is desirable to publish a description of them and their adaptations and to point out the conditions under which they are most likely to prove of value.

In dealing with this new group it was necessary to make a very comprehensive varietal study in connection with the work of agronomic improvement. In order to make permanent the records concerning the whole series of about fifty introductions, a description of each is given under the serial number used to designate it by the Office of Foreign Seed and Plant Introduction of this Bureau.

Thanks are due to the many explorers, missionaries, consular officers, and others who have assisted in procuring the seeds of these varieties. Full acknowledgment of their assistance has been made in connection with the description of the various introductions. The author wishes also to express his obligation to Miss M. E. Holland for assistance in determining the colors of the seeds and glumes and to Mr. B. E. Rothgeb and Mr. Karl H. Townsend for assistance in measuring plants, leaves, panicles, and seeds.

Figures 1, 2, 3, 4, 5, 6, 7, and 13 are from photographs made or obtained in China by Mr. Frank N. Meyer, Agricultural Explorer of this Bureau.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE KAOLIANGS: A NEW GROUP OF GRAIN SORGHUMS.

INTRODUCTION.

The kaoliangs comprise a group of grain-producing sorghums only recently introduced into cultivation and entirely new to the literature of this country. For about 13 years various agencies employed by or cooperating with the United States Department of Agriculture have been forwarding samples of kaoliang seed. These seeds have been sown at various points and the resulting crops studied from the two standpoints of relationship and value. Many data have been accumulated. Some of the varieties have been found to be of agronomic importance in parts of the United States. Since they have now become the property of both experimenters and farmers, it is desirable to present all available data on the group. There follows a brief discussion of the origin, culture, and use of the kaoliangs in their native home and a full description of the important varieties and their adaptations in this country. To this discussion is appended a description of all introductions made, so far as the records are available.

KAOLIANGS IN EASTERN ASIA.

With the exception of a single variety of sorgo,[1] which is grown locally on Tsungming Island in the mouth of the Yangtze River and occasionally on the adjacent mainland, the kaoliangs are the only sorghums found in eastern Asia, including the Chinese Empire, Japan, and Siberia.

NAMES.

The Chinese name for this group of plants is "kao-liang," meaning, literally, tall millet and pronounced kŏw-lĭ-ang. This has been written in other similar forms, as "kauliang," "kaulien," "gaolan," "gaolien," "goolan," etc. These may represent slight differences in pronunciation by different Chinese or they may be merely the different attempts of Americans to reproduce phonetically the Chinese name.

Among the names applied to kaoliang by Europeans in the East are "tall millet," "great millet," "large millet," "giant millet,"

---

[1] Ball, Carleton R. The History and Distribution of Sorghum. Bulletin 175, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1910, pp. 24-25, 32-33, and fig. 9.

"false millet," and "Barbados millet." Most of these names are used to distinguish it from the smaller species of millet which are also commonly cultivated throughout China and in other parts of Asia as well. These species are *Panicum miliaceum* (proso) and *Chaetochloa* (*Setaria*) *italica* (foxtail millet). The use of the term "Barbados millet" by foreigners in China was noted previous to 1866 by Doolittle,[1] who says:

> The so-called Chinese sugar cane or sorghum is grown very extensively in northern China and is known among foreigners as a kind of millet—the Barbados millet. The Chinese name for it is kauliang.

The name probably arose from the resemblance of certain kaoliangs to that kafir variety grown in Barbados and other islands of the West Indies with which some English residents of China were probably somewhat familiar.

It should be noted here that varieties of kaoliangs have been frequently written about and their seeds sent to this country under the name "glutinous millet." This is an error that has probably arisen through a misapprehension of the species really called "glutinous millet" by the Chinese, probably *Panicum miliaceum*. The venerable Dr. S. P. Barchet, of Shanghai, stated the matter tersely in conversation with the writer, as follows: "The large millet of Shantung Province is not glutinous; the glutinous millets are not sorghums." So far as studied, the seeds of kaoliangs, in common with those of all other groups of sorghums, are comparable to maize in chemical composition and are never gluten bearing, as are the seeds of wheat, for example.

In Japan the general term applied to sorghum is "morokoshi," according to the statements made by Dr. Sawano,[2] of the imperial experiment station at Tokyo, in transmitting three samples of the seed, viz, Agrostology Nos. 1584 to 1586. These three were further designated as "sato-morokoshi" or sugar sorghum; "hoki-morokoshi" or broom sorghum, and "kibi" or "to-kibi," millet or tall millet, respectively. For his full statements, consult these numbers and also Agrostology No. 1576 in the descriptive list of introductions. Rein[3] uses the term "morokoshi" and also "taka-kibi," or high millet.

ORIGIN.

It is probable that this group of sorghums was originially brought into China from India. There is evidence,[4] however, that this introduction took place many centuries ago and that the forms as we now find them in China and Manchuria probably vary considerably from the original importations. Among several hundred varieties of sorghum imported into the United States from India and carefully studied varietally, no duplicates of the Chinese kaoliangs have been found. This fact is not surprising if 10 or 15 centuries have elapsed since their translocation from India to China took place.

---

[1] Doolittle, Justus. Social Life of the Chinese, 1866, p. 43; revised edition, by E. P. Hood, 1868, p. 25.

[2] Sawano, J., in letter of April 23, 1903.

[3] Rein, J. J. Industries of Japan, 1889, p. 51.

[4] Ball, op. cit., pp. 11, 24.

DISTRIBUTION.

The Chinese Empire (Pl. I) has an extreme breadth from south to north of about 2,300 miles, or about 2,500 miles if the island of Hainan is included. The southern boundaries of the provinces of Yunnan and Kwangsi are approximately 21° north latitude, while the northern extremities of Mongolia and Heilungkiang Province in Manchuria reach 54° north latitude. The length of the empire from east to west is, roughly, 3,200 miles. The most eastern point of Kirin Province, Manchuria, touches the meridian of 135° east longitude, while the most western extremity of Chinese Turkestan has less than 74° of east longitude.

In general, the topography of the empire is a series of elevated mountain ranges and plateaus in the central and western parts, declining gradually eastward to a broad and fertile alluvial plain of low elevation. This plain has such a gentle gradient as to make part of it subject at times to disastrous overflow and consequent famine.

From the reports of explorers, missionaries, and others it is known that the kaoliangs are grown more or less extensively over most of the eastern half of the empire.

In China proper they are found from Yunnan, which is the most southwestern province and adjoins Tibet on the southeast, to Chihli in the north and thence south to Shantung and Chekiang. They appear to be found only rarely or not at all in the southeastern alluvial provinces from Fukien and Kiangsi on the east to Kwangtung and Kwangsi on the southwest. These provinces comprise part of the great rice-growing area of China. In general the kaoliangs become increasingly important westward in the piedmont areas up to prohibitive elevations and northward with increased latitude and shorter seasons.

Much has been written about the kaoliangs in North China and Manchuria, but very little about their occurrence in western China. The following note by Wilson,[1] who had then traveled five years in the provinces of Yunnan, Szechwan, and Hupeh, in southwestern China, will be of interest. He says, under the heading "False millet":

> This is the kaoliang of the Chinese, which is largely used in China for making wine. It is cultivated generally throughout central and western China, but not so extensively as in other parts of China, notably Manchuria. The largest areas I noted

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[1] Wilson, E. H. Leaves from My Chinese Notebook. Gardeners' Chronicle, September, 1905, vol. 38, p. 246.

were on the plateaux of Yunnan, the plain of Chentu [1] and the fluviatile areas of the Min and Fo Rivers. Its altitudinal limit is the same as that of maize and, like this latter, it is always a summer crop.

It is in the province of Manchuria, however, that these crops are most abundantly grown and become highly important staples on the farm. They are found commonly in Chosen (Korea) also, and to a lesser extent in Japan. Just to what extent they are grown in Siberia, above the borders of Manchuria and Chosen (Korea), is not known. Seed has been obtained from Usuri Province, northeast of Chosen, and also (S. P. I. No. 939) from Nertchinsk in Trans-Baikalia, at 51° north latitude. It is not stated, however, in either case whether it was grown in these provinces or merely imported as a cereal.

Kaoliang was prominently mentioned in Manchuria under the name "tall millet" during the progress of the Russo-Japanese War. This fact developed from the frequent maneuvering of infantry, and even of cavalry also, under cover of the shelter afforded by fields of this tall-growing crop.

CULTURE.

While the native methods of growing the kaoliang crop would seem rather crude to the American farmer, accustomed to the use of improved machinery, they are really quite thoroughly systematized. So far as the practices obtaining in Manchuria are concerned, the writer can do no better than quote from a paper by the consular officer of the United States at Newchwang. Manchuria is the banner kaoliang-producing region and Newchwang is not only situated in the region of production but is the port through which most of the Manchurian exports pass. The report of Consul General Sammons [2] is as follows:

> *Holcus sorghum, or tall millet.*—Holcus sorghum, or tall or giant millet, of which the Chinese name is kaoliang, is planted in drills in the deep, rich loam throughout Manchuria. The seed is sown by hand and is then covered with manure. Stone rollers are then passed over the drills. When the shoots are 2 or 3 inches high they are thinned to about 18 inches apart. The weeds are carefully destroyed, and, except the earthing up of the roots or "hilling" the plants, as in caring for Indian corn in the United States, no further attention is required until harvest time in September. Should there be heavy rains in May the plants may be greatly damaged by roots losing their hold on the soil, resulting in the plant being blown over. Too much rain or a lack of rain may prevent the seed from ripening; but as a rule, as is the case this season, a good crop is secured.
>
> During the early part of September, the stalks, having reached a height of from 8 to 10 feet, and the heads having turned purple—caused by the small, dark purple cases which contain the grain—they are cut down near the roots. This usually takes place toward the close of the month. The process of thrashing consists of cutting off the

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[1] Chentu (Chengtu) and the Min and Fo (Fu) rivers are in Szechwan.

[2] Sammons, Thomas. Manchuria: Manufactures and Agriculture. Monthly Consular and Trade Reports, No. 301, October, 1905, pp. 52-54.

heads of the stalks, spreading them on the floor, and thrashing them with a stone roller drawn by some domestic animal. This is completed in about four hours. The grain is then passed through a winnowing machine or tossed up in the air, after being separated from the empty heads, which are used either for fuel or in the manufacture of brooms. The now cleaned, but unhusked, grain is put in sacks and is ready for the market, being sold for fodder. To be fit for human consumption it must still pass through the process of husking, which consists of placing the grain on a circular stone floor, passing a circular stone roller over it, which crushes the husks, and separating the grain from the husks.

It is estimated that 8 pounds of the seed will sow an acre of ground and that the yield in grain will be half a ton if the crop is good. There is in Manchuria practically an inexhaustible supply of giant millet stalks, but these stalks are by no means a valueless or useless quantity. It is estimated that the product of an acre (6 Chinese mu) will weigh from 1¼ to 1½ tons of 2,000 pounds. The value of the dry stalks is approximately $5 gold per ton. The stalks are usually sold in bundles of about 10 stalks. In the Chinese method of reckoning there are about 75 bundles to each mu, and 100 of these bundles to 320 catties (a catty is equal to 1⅓ pounds). The native price is $1 to $2.50 (Mexican) to the 100 bundles, equivalent to 50 cents to $1.25 gold.

Mr. Frank N. Meyer, Agricultural Explorer of this Bureau, who has traveled widely in Manchuria and North China, has kindly furnished the following original account of the culture of kaoliang in those areas:

It seems that sorghum was introduced into China from India in the second century of our calendar. It soon spread until now it has become the staple crop of the North, and it has developed a great number of varieties. The shortest variety I ever saw was found growing along the coast of Shantung and was barely three feet in height, with very dense heads of seeds, while on some of the low, rich land near Tientsin varieties may be found that tower 20 feet in height and often have loose, spreading heads. Then there are white, light-brown, and dark-brown seeded varieties, and forms with white, brown, and black hulls; erect-headed ones, drooping ones, and hybrids between all of them. [See fig. 1.] In some fields, where the grower has not been very careful about the selection of his seeds, one might easily find 30 or 40 different forms in an hour's time, some even ripening fully a fortnight later than others, which can be explained by the fact that the Chinese only cut those heads that are ripe, leaving the others to ripen later on. Later, the seeds of both early and late sorts are often mixed together again, and the next year's crop is still worse in irregularity of ripening.

The method of growing the kaoliang in North China is as follows: The soil on which the grain is going to be planted has been plowed in the autumn, has lain rough and unbroken during the winter, and is manured and plowed in the spring. During the month of May the seeds which, by the way, often have been soaked in water overnight, are sown in rows in hills 2 to 3 feet apart, and the rows always run north and south. A few days later the young plants appear above the ground. They do not make much growth until the first summer rains, which usually begin in the latter part of June, although also often not until early July. The fields are regularly hoed and cultivated, even if the plants do not make much progress. When once the rains have started, however, the young sorghum shoots up with an amazing quickness and can almost be seen to grow.

As soon as the plants are a foot or so high, the hills are thinned and generally only one plant is left. By about the middle of August the kaoliang has headed and when the seeds have set well a few weeks later, one may see in large fields hundreds of workingmen pulling off the leaves from the plants, leaving only a few at the top. The Chinese claim that if they did not do this the grain would not ripen and the soil would not dry sufficiently to keep the plants healthy. Whatever truth there may be in this I do not know, but the fact is that these leaves are most carefully dried, packed into bundles, and kept as a winter food for the domestic animals. In a country without meadows, like China, these leaves take the place of hay.

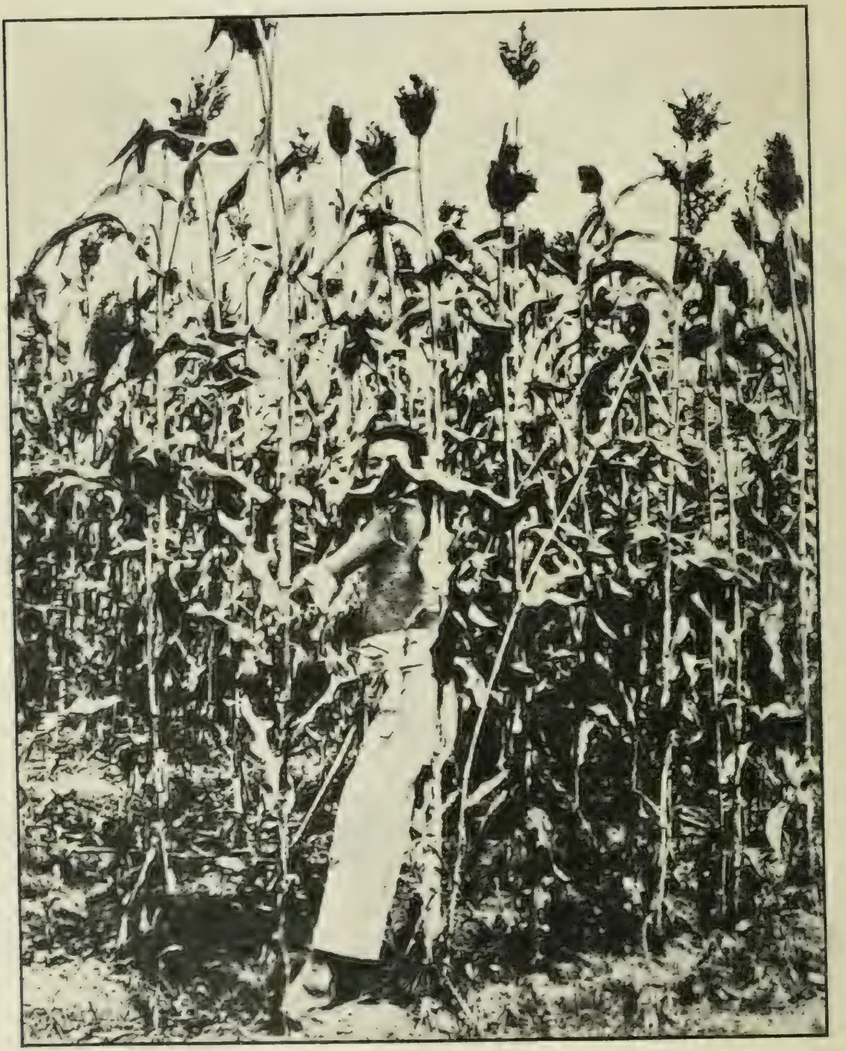

FIG. 1.—Field of kaoliang 10 feet high, in the vicinity of Harbin, Manchuria. (Photographed by Frank N. Meyer.)

When the seeds are at last sufficiently ripe, armies of men turn out again in the fields, and either cut the whole plants down and let them dry in sheaves, which method they use in the larger fields of Manchuria [see figs. 2 and 3], or, where the population is dense and the fields smaller, the people cut off the heads first and store them away in safety, for there is much crop robbing in China. Later on they come back and cut the stalks down.

These harvested heads are spread out every day in the sun, in the yards, on matting, etc. When sufficiently dry, they are spread out again on a clay thrashing floor, and stone rollers [see fig. 4] hitched to horses, mules, donkeys, old men, women, or boys, are dragged over them. In this primitive way the seeds are thrashed out and later on winnowed, all by hand labor, and, when clean, are stored away in earthen jars, in baskets smeared over with clay, and in sacks. They form a very important item in the agricultural productions of Manchuria and North China.

The method of culture employed on Tsungming Island in the mouth of the Yangtze River, Kiangsu Province, China, is briefly given by Dr. S. P. Barchet,[1] interpreter at the American consulate, Shanghai, in transmitting the seed of two varieties, S. P. I. Nos. 22911 and 22912. He writes:

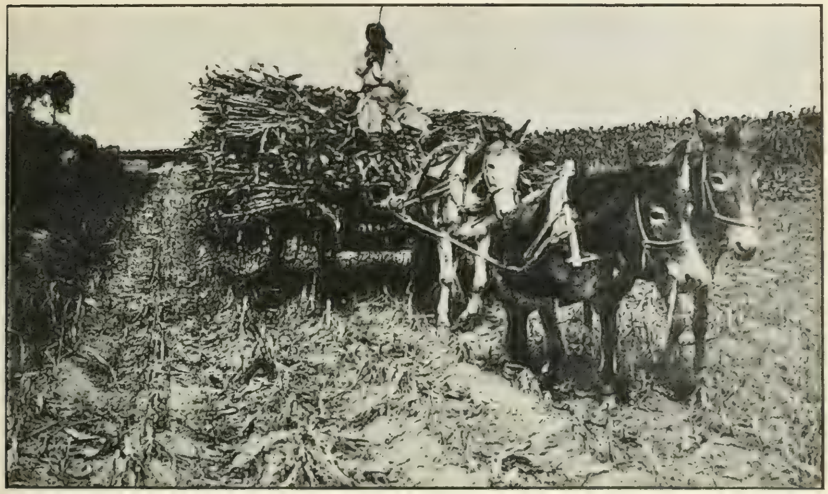

FIG. 2.—Hauling the kaoliang crop from the field on a two-wheeled cart, Harbin, Manchuria. (Photographed by Frank N. Meyer.)

> The white variety (S. P. I. No. 22912) is considered inferior to the red (S. P. I. No. 22911, Brown), though planted in the same way. It is planted in richly manured land, in rows 6 inches wide covered lightly with half an inch of earth. If plants come up too thick or crowded, the plants which should be removed are not pulled, but cut off with a sharp knife, so as not to disturb the roots of neighboring plants.

In Japan, as noted, the sorghum plant is not widely distributed and it is only sparingly cultivated in the localities where it has been introduced. Rein[2] states:

> Guinea corn or Durrah, Japanese morokoshi (*Sorghum vulgare*, Pers[e]; *Holcus sorghum*, L.), called also taka-kibi (high millet), is of only small importance for Japan.

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[1] Seeds and Plants Imported during the Period from April 1 to June 30, 1908. Bulletin 142, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, pp. 42–43.

[2] Rein, J. J. Industries of Japan, 1889, p. 51.

This grain is seldom found except along the borders of fields, encircling them in a furrow, and even this but rarely. It is raised in April, in a seed bed. Later, having attained a height of about 15 cm., it is transplanted at intervals of from 25 to 30 cm. It is harvested in September. The same holds good for the long-panicled form, the broom corn, so often grown in northern Italy, and of whose panicles brooms are also made in eastern Asia.

Consul General Bellows,[1] of Yokohama, in transmitting the seed of Agrostology No. 1576, says:

I have the honor to transmit a package of Japanese sorghum seed of the kind known as "morokoshi kibi." Messrs. L. Boehmer & Co., horticulturists, of Yokohama, who have furnished this seed without charge, inform me that this sorghum "is of very little importance in Japan, being generally planted along the borders of fields only, in order to protect the field crops against winds, etc. In some parts of the country where rice and other cereals do not grow sorghum is to a certain extent cultivated as a field crop. It is sown in April in seed beds and later transplanted at intervals of 8 or 10 inches."

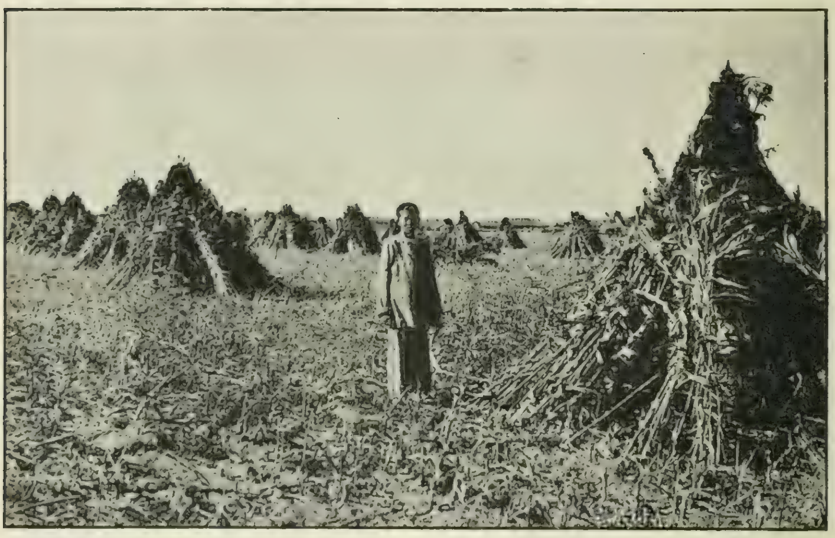

FIG. 3.—Field of kaoliang curing in the shock, Harbin, Manchuria. (Photographed by Frank N. Meyer.

Of the sato-morokoshi, or sugar sorghum (Agrostology No. 1584), Dr. Sawano [2] says:

This plant was introduced to this country from China about 28 years ago. For many years we tried to prepare sugar from it in many localities, but with poor success, on account of climatic and other circumstances. At the present time it was difficult to obtain even the small quantity sent.

The 28-year period mentioned by Sawano dates almost exactly from the publication of Collins's [3] paper on the Chinese sorgo, which doubtless led the Japanese to investigate the saccharine variety of China. Be that as it may, the sample sent was not the Chinese sorgo, but a Brown kaoliang, different from the other (No. 1586) which accompanied it.

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[1] E. C. Bellows, in letter of March 6, 1903.

[2] Letter from J. Sawano, April 23, 1903.

[3] Collins, Varnum D. Sorgo, or the Northern Chinese Sugar Cane. Journal of North China Branch, Royal Asiatic Society, n. s., vol. 2, December, 1865, p. 91.

Of the tall millet, or to-kibi, Sawano says:

> It is generally planted along the boundary of a farm plat as a wind shelter for another principal summer crop. Its cultivation is very easy, and, indeed, the farmer does not pay much attention to it. In May or June the seeds are sown in one or two rows. It is harvested about October or November, when the heads turn yellowish in color.

USES.

The primary use of the kaoliang crop throughout most of the region where it is grown is for human food and the feeding of farm animals.

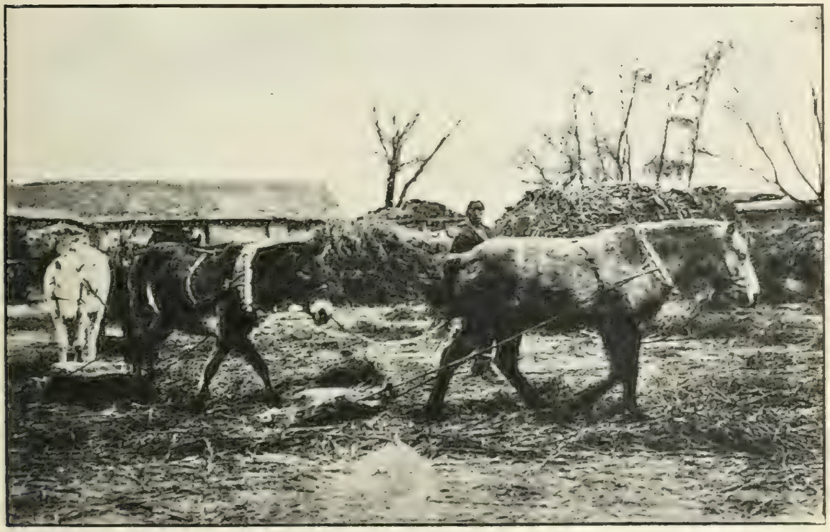

FIG. 4.—Thrashing kaoliang seed from the harvested heads by means of stone rollers drawn by horses or mules, near Harbin, Manchuria. (Photographed by Frank N. Meyer.)

It has, however, a great many secondary uses, due to the ingenuity and thriftiness of the Chinese in matters of economic detail. Its importance to the people of Manchuria and the uses to which they put it are well shown in the following quotation from Consul General Sammons,[1] of Newchwang:

> The giant millet is no doubt the most valuable product of Manchuria to the natives. It is the staple food—that is, the seed—of the people, and is fed likewise to the beasts of burden. The seed is also used in distilling spirits or sanshu. Practically all of the giant millet is consumed in the country where it is raised in such great abundance. The stalks are not only used for fuel in winter, but in making mats. These are manufactured by hand from the outer leaves. Compound or yard fences [fig. 5] are made from the stalks. They also enter into house building and in constructing small bridges. Even the roots are used. In the spring when the fields are plowed the

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[1] Sammons, op. cit., pp. 53–54.

roots are saved and burned for fuel. * * * The empty heads are used either for fuel or in the manufacture of brooms.

The missionary previously mentioned, Mr. Doolittle, writing of the native life and customs in Fukien Province in 1866, says,[1] concerning the uses of kaoliang by the people of northern China:

> They make a coarse kind of bread from the flour of the seed of the kauliang, eaten principally by the poorer classes. The best kind of Chinese whisky, often called Chinese wine, is distilled from the seeds. The stalks are used for fuel, for lathing in the partitions of houses, for slight and temporary fences, etc. Numerous and immense fuel yards, consisting entirely of the dried stalks of the kauliang, are found at Tientsin and many other cities in the north of China.

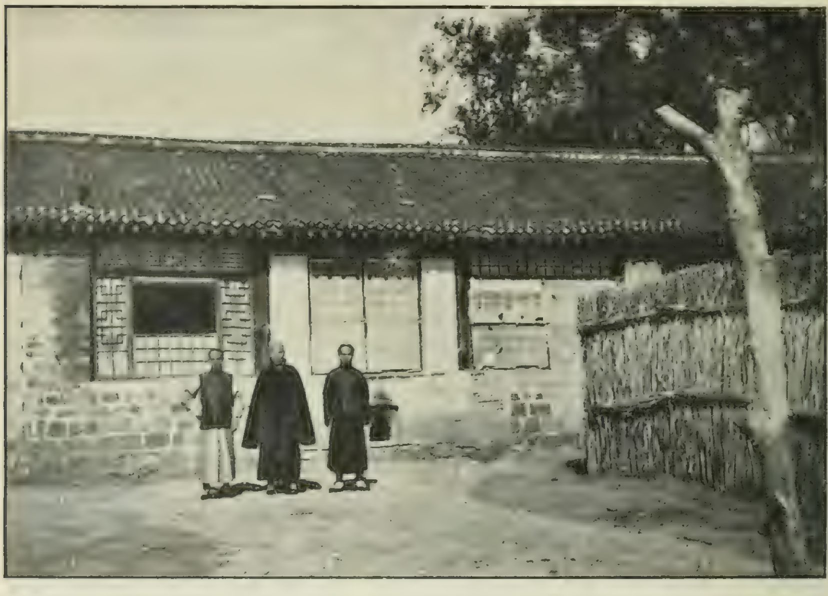

FIG. 5.—Kaoliang stalks used as a fence at Changli, Chihli, China, October 11, 1907. (Photographed by Frank N. Meyer.)

Mr. Frank N. Meyer, Agricultural Explorer for the Office of Foreign Seed and Plant Introduction of this Bureau, has accumulated interesting information and photographs showing the uses of kaoliang in North China. In transmitting S. P. I. No. 17921, a brown-seeded sort collected at Peesan, Chihli, he states:[2]

> (No. 22, *a*.) A variety with dark-brown seeds, universally used throughout North China as fodder for domestic animals. The stems of sorghum are used in building houses, the stalks being embedded in the mud walls; also for making fences, baskets, mats, tying and roofing material, and for fuel.

Figures 5 and 6 illustrate the use of stalks in making fences and baskets.

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[1] Doolittle, Justus. Social Life of the Chinese, 1866, p. 43; revised edition by E. P. Hood, 1868, p. 25.

[2] Seeds and Plants Imported during the Period from December, 1905, to July, 1906. Bulletin 106, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1907, p. 60.

After his return from Manchuria Mr. Meyer prepared for the writer the following statement concerning the use to which the kaoliang is put by the Chinese:

> Of the many crops the Chinese grow in North China, the sorghum is unmistakably the most important and the most useful. Without it life in a great part of North China and Manchuria would be almost impossible, for the variety of uses to which the kaoliang is put are legion, and it could not very well be replaced by any other single crop.
>
> The light-colored varieties are ground into flour, out of which cakes are made, or they are simply boiled in water and served in the form of a gruel to the Chinese laborers, and it is amazing to see how much a Chinese can eat of it. I have seen my own interpreter eat three big bowlfuls for breakfast in the early morning and still feel comfortable. The dark-colored seeds are considered coarser and are used for distilling purposes and as fodder for horses and cattle. Nearly all of the fiery spirits that are used in North China (the so-called samshu) are distilled from these seeds, which are carted about the country in amazing quantities. As a feed for horses and mules one certainly can say that the kaoliang seeds, especially the dark-colored ones, in North China and Manchuria, take the same place that oats do with us.
>
> The stalks of kaoliang are almost as valuable to the Chinese as the grain itself. In the semiarid north, where all of the wild, arboreal vegetation has either been exterminated, or at least has been reduced to such an extent as not to form an important item any longer, one finds that the stalks are the chief supply of fuel. They are used to cook the food, to heat the brick bedsteads in winter time, to boil the water for

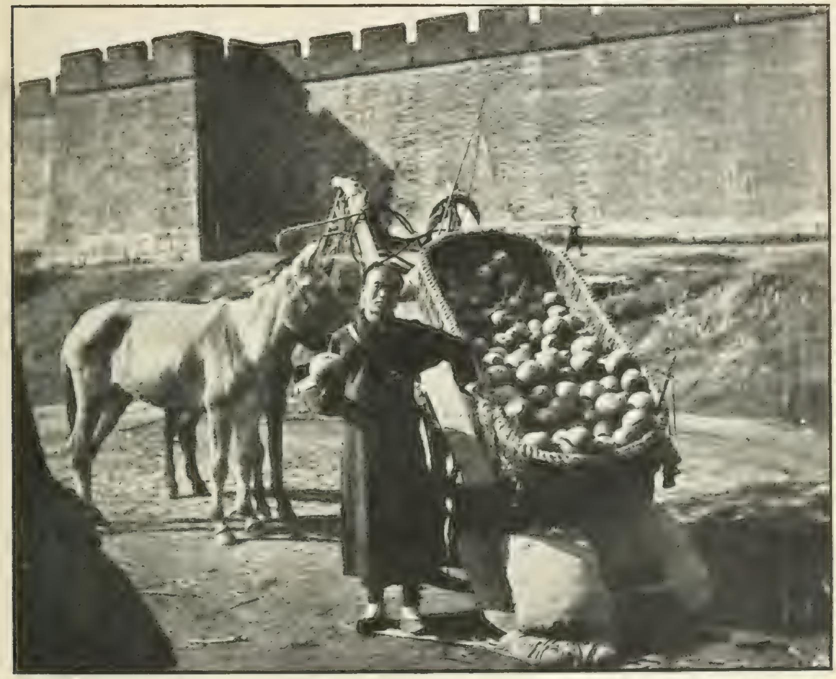

FIG. 6.—Basket made of kaoliang stalks, containing giant red radishes, outside the city wall of Changli, Chihli, China, October 15, 1907. (Photographed by Frank N. Meyer.)

tea; in fact, are used whenever heat is needed. Another important rôle they play is in the fine fencing material they furnish. In North China, in winter time, the icy wind blows with great violence all over the plains. To protect themselves, at the approach of the cold season the Chinese build fences around their houses, yards, pigpens, etc., and comfort would certainly be still more reduced in North China if these kaoliang-stem windbreaks were unobtainable.

These stalks are used also as supports for plants in the vegetable gardens. They serve as poles for beans, cucumbers, and yams. [See fig. 7.] They also lend themselves to basket and matting making, and in Shantung I even observed highly colored varieties that were grown for the express purpose of furnishing fancy basket and matting materials. In making the finer qualities of baskets the outer skin only is used, being split off by hand and woven into the various articles desired by skilled men and women. For large, coarse baskets, however, the whole stems are taken while they are still fresh, for when once dry they can not be manipulated very well.

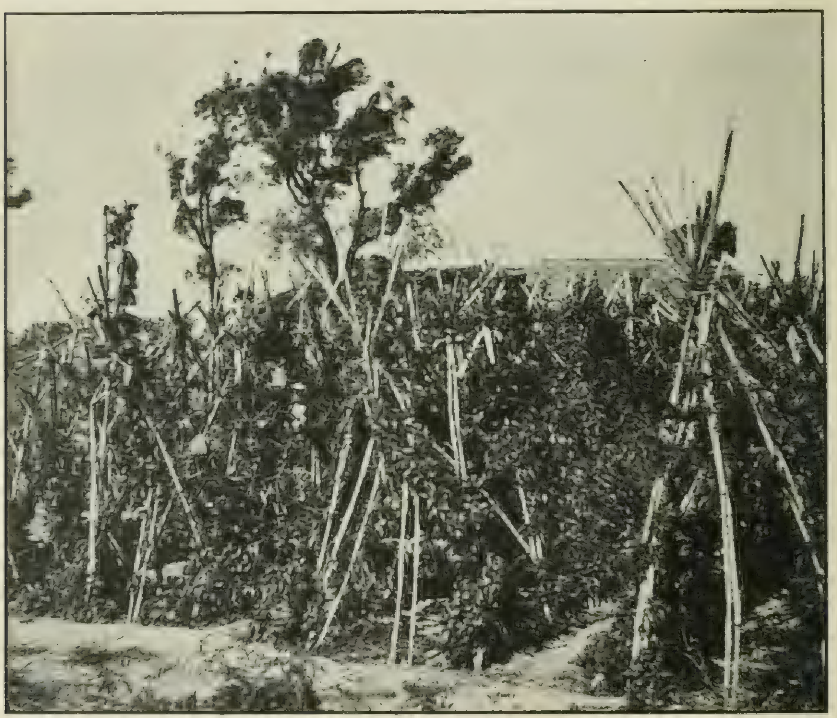

FIG. 7.—Kaoliang stalks used as poles to support a yam, *Dioscorea* sp., Changtchon, Chihli, China, October 2, 1907. (Photographed by Frank N. Meyer.)

Still another use the Chinese have for these stems is to chop them up, mix them with a few handfuls of boiled black soy beans, or kaoliang seeds, or bean cake, and serve them to their hard-working horses, mules, and donkeys—in the greater part of North China about the only food the draft animals ever get.

One would think by this time that the list of uses for the stems was pretty nearly exhausted, but there are still a few more; for instance, when an ordinary Chinese laborer builds himself a home he first erects a frame of poplar and willow poles; between these he places kaoliang stems. The whole frame is then smeared over with mud, in which chopped-up straw or hairs has been mixed, and the house is then ready to move into. In the primitive greenhouses of the Chinese these sorghum stems serve as bars to hold the paper windows. They also constitute the frame of the roof, upon which the clay is smeared.

There are several minor uses yet for these stems, such as frames for kites, paper animals, playthings for children, etc., but I am afraid that the list would be too long to add here.

A last item about the kaoliang: Even the roots are not allowed to stay in the ground, but are carefully grubbed out by a stroke of a peculiar hoe or grub and a pull with one hand, are dried, stacked up in bundles, and sold and used all over the land for fuel. One certainly might ask, what would the farmer of North China do if he had no kaoliang to fall back upon.

In the "Report of an Investigation of the Scientific and Economic Relations of the Sorghum Sugar Industry," made by a special committee of the National Academy of Sciences, are given some notes on the uses of kaoliang, contributed by Dr. S. Wells Williams,[1] professor of oriental languages at Yale University. Like nearly all writers previous to the last few years, he confuses the sorgo grown locally on and near Tsungming Island, Chekiang, with the kaoliangs grown generally throughout northern China. The uses he mentions are for the kaoliang plant, except perhaps the reference to the practice of chewing the stems. His statements regarding its uses are as follows:

> The Chinese are abundantly supplied with good and cheap sugar in all portions of their empire, coming from the sugar canes of the south; they have, consequently, no need of other sources than this plant. Their uses for sorghum are various—fodder for cattle from its leaves, fuel, wattles for fences, etc., from the stalks. In binding several of these together and cementing with clay they get a cheap substitute for posts, while the stalks in many ways take the place of timber.
>
> Many varieties of the grain, black, red, and white, are known to the farmer. Its seeds, which are abundant, are used for making a sort of spirits, also occasionally for feeding to horses, mules, and camels.
>
> The plant is almost wholly confined in its cultivation to the provinces north of the Yangtze River and forms in this region one of the principal crops. It is not employed as food for man save in times of famine and great stress. When ripe the grain is about the size of duck shot. * * *
>
> The 20 or more varieties[2] which President Angell brought from China could probably be increased in number if the collection were made from a more extended area.
>
> The uses of this plant for fuel tend to increase attention to the development of its stalk rather than the grain.
>
> The plant often attains a height of 15 or 16 feet. The common practice of stripping off all the leaves within reach upon the growing stalk for feeding cattle increases very materially its woody fiber. Cutting the stems while in their prime of growth and chewing them green, as Southerners do the sugar cane, is not unusual in the North.

Kaoliang becomes less extensively grown as one goes southward in China, but the number of uses to which it is put does not diminish in proportion. Chekiang is the most southern coastal province from which samples have been received. A brown-seeded kaoliang (S. P. I. No. 16792) was obtained with other seeds at Hangchow, in Chekiang, by Vice Consul Frederick D. Cloud in 1905. In sending them, after discussing the mixing of kaoliang seed with soy beans and other forage for horse feed, he says:[1]

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[1] Williams, S. Wells. On the Sorghum (Kow-liang) of China. Report, National Academy of Sciences, November, 1882, pp. 57–58. 1883.

[2] Collier, Peter. Sorghum. American Agriculturist, vol. 45, 1886, p. 153.

> Perhaps the "kaoliang" is the most highly prized of all forage plants grown in China. No part of the plant goes to waste. Two or three weeks before the plant matures and the seed is ripe the farmer strips nearly all the blades from the plant, ties them in bundles, allows them to cure in the sun for a few days, and then stacks them away indoors. All through the winter these blades are keenly relished by horses and donkeys. Then the seeds are gathered, combed out, and marketed. Several varieties of alcohol and wines are made from these seeds, and the deadly native drink "sam-shu"—at least one variety of it—is made from "kaoliang" seed. The seed makes excellent food for stock of all kinds. The long stalks are thrown on the thrashing floor, rolled flat by heavy stone rollers, carefully cleaned of all particles of pith, and woven into a great variety of mats and matting, suitable for use on floors, for window shades, or for the roofs of native houses and sheds. These stalks are also extensively used for fuel by the farming class. It is a most valuable crop and may be found throughout all the northern provinces. Not grown much as far south as Hangchow.

As previously noted, Wilson[2] states that in southwestern China, in the provinces of Yunnan and Szechwan, 90 per cent of the seed is used for making wine, being only occasionally employed for food, more particularly in the mountain districts. Several years later, while employed as a collector for the Arnold Arboretum, Jamaica Plain, Mass., he obtained three lots of brown-seeded kaoliang (S. P. I. Nos. 21676–21678) at or near Ichang, in the province of Hupeh. In the notes transmitted with the seed he says:[3]

> In this part of the Yangtze Valley the sole use of sorghum (kaoliang) is for making wine and spirits. I can find no record of its being used for food, even by the peasants.

As noted by Rein,[4] Bellows,[5] and Sawano,[6] the chief use of kaoliang in Japan is for a windbreak or border about fields, while forms with longer panicles and shortened rachis are utilized for making brooms. Occasionally it is used for human food, concerning which Sawano says: "The seeds or grains are used generally for a kind of cake or pudding, which we call 'mochi.'"

The different uses tabulated below have been specified by the collectors of the samples of seeds listed by number and by the authors whose names are given. The full text of the notes made by the collectors will be found in connection with the descriptions arranged numerically on later pages of this bulletin. It is probable that there are numerous other local uses for the plant which are not recorded in the tabulated list.

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[1] Seeds and Plants Imported during the Period from December, 1903, to December, 1905. Bulletin 97, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1907, pp. 237–238.

[2] Wilson, E. H., loc. cit.

[3] Seeds and Plants Imported during the Period from July, 1906, to December 31, 1907. Bulletin 132, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1908, p. 175.

[4] Rein, J. J., loc cit.

[5] Bellows, E. C., op. cit.

[6] Sawano, J., op. cit.

TABLE I.—*Classified uses of the kaoliang plant in eastern Asia.*

Material used and nature of use.	Designation of seed samples representing varieties so used.	Citation of other authorities for such use.
Grain:		
Feed	S. P. I. Nos. 6604, 16792, 17921, 17922, 21078, 28057–28058.	Meyer, Sammons, Williams.
Food	Agrost. No. 1586; S. P. I. Nos. 3863, 6406, 6411, 6604, 6710, 17920, 17922, 17923, 21077, 21078.	Doolittle, Meyer, Sammons.
Liquor	S. P. I. Nos. 3863, 4905, 6604, 16792, 21676–21678.	Doolittle, Meyer, Sammons, Williams, Wilson.
Heads:		
Brooms	Agrost. No. 1585; S. P. I. Nos. 18613, 20627, 22012.	Rein, Sammons.
Fuel		Sammons.
Leaves:		
Fodder	S. P. I. Nos. 3863, 16792, 17923, 28057–28058.	Meyer, Sammons, Williams.
Mats		Sammons.
Roots:		
Fuel	S. P. I. No. 17923	Meyer, Sammons.
Stalk:		
Baskets	S. P. I. No. 17921	Meyer (fig. 6).
Bridges		Sammons.
Building	S. P. I. No. 17921	Meyer, Sammons, Williams.
Fences and hedges	S. P. I. Nos. 3863, 17921	Doolittle, Meyer (fig. 5), Sammons, Williams.
Fodder		Meyer.
Fuel	S. P. I. Nos. 3863, 16792, 17921, 28057–28058.	Doolittle, Meyer, Sammons, Williams.
Kite frames		Meyer.
Lath		Doolittle, Meyer.
Matting	S. P. I. Nos. 16792, 17921, 22011 (red)	Meyer, Sammons.
Playthings		Meyer.
Posts		Williams.
Sugar	Agrost. No. 1584	
Thatching	S. P. I. Nos. 16792, 17921	Sammons.
Tying material	S. P. I. No. 17921	
Trellis		Meyer (fig. 7).
Window frames		Meyer.
Window shades	S. P. I. No. 16792	
Whole plant:		
Alkali-resistant crop	S. P. I. Nos. 18610–18612, 19187, 22012	
Windbreak	Agrost. Nos. 1576, 1586	Meyer, Rein.

KAOLIANGS IN THE UNITED STATES.

INTRODUCTION OF VARIETIES.

It is possible that seeds of kaoliang varieties were sent to this country previous to 1860, but no record of such introduction has come to the attention of the writer. At various times from 1793 to 1861, kaoliangs had been noted by English diplomatic officers and others[1] as growing abundantly along the Pei from Taku to considerably above Tientsin in Chihli. There is no indication, however, of any attempts to introduce this crop into western lands.

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[1] Bretschneider, Emil. History of European Botanical Discoveries in China, vol. 1, 1898, pp. 157–158, 226, 513.

Fortune, Robert. A Narrative of a Journey to the Capitals of Japan and China, 1863, pp. 316, 346.

HISTORY OF EARLY INTRODUCTIONS.

In 1865 Mr. Varnum D. Collins was sent to China to study the methods supposedly used by the Chinese in making sirup and sugar from sorgo.[1] He was also commissioned to get additional sorgo varieties for use in sugar-making experiments in the United States. In the paper cited he makes no reference to the sending of any seeds of kaoliangs to this country. From other sources, however, we know that four lots of seeds were received from him and that some of them were kaoliangs.[2] These were probably sent after his paper was written. There is no record of what became of them and it is probable that when the stems were found lacking in saccharine juice they were discarded without even so much as having been described. They constitute the first recorded introduction of kaoliangs into the United States.

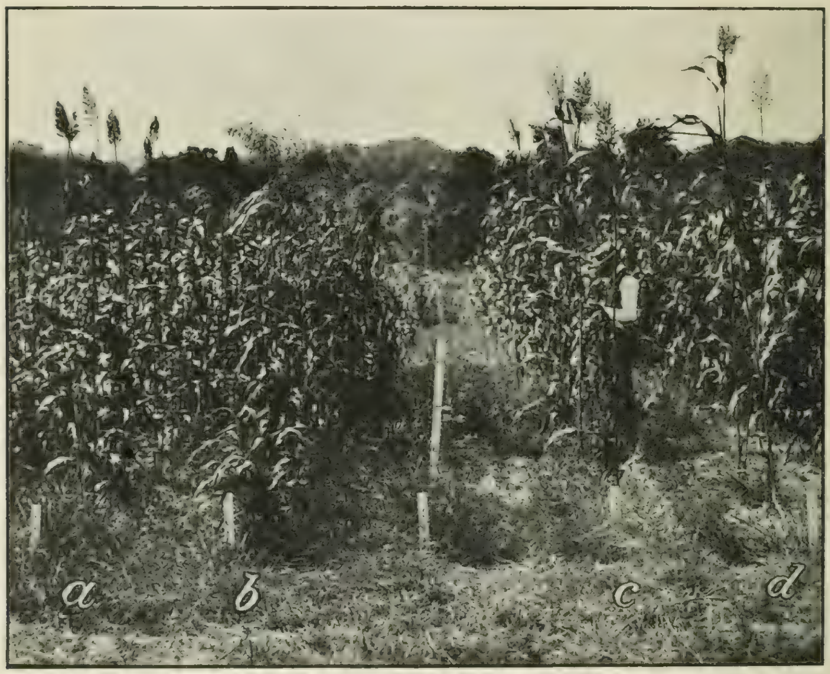

FIG. 8.—Plants of Brown kaoliang varieties, Arlington Experimental Farm, Va., September 22, 1903: *a*, Meyer Brown (Agrost. No. 1454, S. P. I. No. 6411), from Chosen (Korea); *b*, Baird Brush (Agrost. No. 1453, S. P. I. No. 6406), from Chosen (Korea); *c*, Hansen Brown (Agrost. No. 1448, S. P. I. No. 3863), from China; *d*, Hansen Brown (Agrost. No. 1444), "Red" from California experiment station.

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[1] Collins, Varnum D., loc. cit., p. 91; Clough, William J., Sorgo Journal (editorial), vol. 7, 1869, p. 91; Williams, S. Wells, Report, National Academy of Sciences, 1882, p. 57, 1883.

[2] Clough, loc. cit.

Dr. Peter Collier, formerly chemist of the Department of Agriculture, states [1] that in 1881 he received, through President Angell, minister to China, six varieties of sorghum seed, the names of which were as follows:

Hwong-mao-nien-liang—Yellow-cap-glutinous-millet.
San-sui-hung-liang—Separated-headstalks-red-millet.
San-sui-pai-liang—Separated-headstalks-white-millet.
Er-chiu-hung-liang—Second-autumn-red-millet.
Ma-wei-nien-liang—Horse-tail-glutinous-millet.
Ta-min-hung-liang—Large-people's-red-millet.

The third and fourth varieties are depicted in plates 3 and 4 of Collier's work. Apparently they represent, respectively, a white-seeded sort with large, loose panicles, similar to S. P. I. No. 17920, and a brown-seeded variety with small and very compact panicles resembling S. P. I. No. 18518.

These six varieties, which came from Peking, were grown by Dr. Collier at Washington, D. C., in 1882, with many other varieties from other countries. That they were all true kaoliangs is evident from his comparison [2] of them chemically with saccharine varieties from other sources. He states, further, that all except the first of these Chinese sorts belong to his fifth class; that is, they produce a single stalk from each seed, with no suckers from the roots but with branches at every joint of the parent stalk. The first variety produced sometimes two main stalks from a seed and sometimes a single stalk, and later produced suckers from the roots.

Several references [3] have also been found to 20 varieties of non-saccharine sorghum said to have been received from President Angell, who had obtained them in and about Peking. From an article by Dr. Collier [4] it appears that these 20 lots did not represent a later shipment, but that the 6 lots of seed previously discussed were found, on growing them, to represent 20 different forms.

A few years after the testing of the varieties obtained in China by President Angell, the Kansas Agricultural Experiment Station [5] grew and reported on three varieties in 1890. They were obtained through Consul B. F. Franklin at Hankow, which is in Hupeh Province and is also the source of S. P. I. Nos. 4905 and 6604.

These three varieties were described quite carefully, except that in the case of two of them the seeds are recorded as varying from white to red and, in one case, even to black, all in the same head. The apparent mixture of white and colored seeds in the same head is probably due to the well-known bleaching of the yellowish ovary just before the appearance of the pigment which gives the final color to the seed. There is no later record showing the final disposition of these three varieties and it is probable that they were discarded in favor of the kafirs, just then being introduced into cultivation.

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[1] Collier, Peter. Sorghum: Its Culture and Manufacture, 1884, pls. 3 and 4, p. 76.

[2] Collier, op. cit., pp. 101–107, 535–537.

[3] Williams, S. Wells. On the Sorghum (Kaoliang) of China. Report, National Academy of Sciences, 1882, p. 58 [1883]; also quoted by Collier, op. cit., p. 52.

Denton, A. A., and Crampton, C. A. Report on Sorghum Experiments at Sterling, Kans. Bulletin 20, Bureau of Chemistry, U. S. Department of Agriculture, 1889, p. 112.

[4] Collier, Peter. Sorghum. American Agriculturist, vol. 45, 1886, p. 153.

[5] Georgeson, C. C. Experiments with Forage Plants. Bulletin 18, Kansas Agricultural Experiment Station, 1890, pp. 182–183.

RECENT INTRODUCTIONS AND THEIR SOURCES.

The official introduction of kaoliang varieties into the United States by the United States Department of Agriculture began with the receipt of S. P. I. No. 225 from North China in the year 1898. Between that time and the close of the year 1910 a total of 51 direct and 3 indirect introductions from eastern Asia had been made.

All varieties obtained or distributed directly by the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry are given serial numbers called S. P. I. numbers. When such varieties are tested by the other offices of the Bureau interested in various crops, they are usually given a second number by the office testing them. The two offices which have tested kaoliangs are the former Division of Agrostology and the present Office of Grain Investigations. The writer has had charge of the study of these varieties in both offices.

In Table II these different kinds of numbers are arranged serially in parallel columns. The numbers in column 1 are those applied to a few of the earlier introductions by the Division of Agrostology. The numbers in column 2 are those given by the Office of Grain Investigations. Column 3 contains the original introduction numbers given by the Office of Foreign Seed and Plant Introduction so far as the varieties were obtained by that office. In order to maintain the serial arrangement it has been necessary to enter certain numbers twice. In such cases one entry is not in its proper numerical sequence and is therefore placed in parentheses. Where more than one S. P. I. number is found opposite a G. I. number it indicates that successive crops of improved seed grown in this country have been given new S. P. I. numbers to facilitate the records of distribution. Where an S. P. I. number has no parallel G. I. number it means that that introduction was not grown by the Office of Grain Investigations. In the single case where a G. I. number has no parallel S. P. I. number, viz, G. I. No. 28, it represents an independent accession, similar to those made by the former Division of Agrostology. This table shows also the source of the original seed and the variety of the kaoliang group to which it belongs.

TABLE II.—*List of numbers assigned to kaoliangs by the Division of Agrostology, by the Office of Grain Investigations, and by the Office of Foreign Seed and Plant Introduction, with varietal name and source of original seed.*

Agrost. No.	G. I. No.	S. P. I. No.	Varietal name.	Source.
		225	Hansen Brown	North China.
		939	Manchu Brown	Trans-Baikalia, Siberia.
1442			Brill Blackhull	California Experiment Station.
1443			Mukden White	Do.
1444			Hansen Brown	Do.
1448		3863	do	China.
1450		4905	Tokyo Brown	Hupeh, China.
1453		6406	Baird Brush	Chosen (Korea).
1454		6411	Meyer Brown	Do.
1455	(326)	6604	Hansen Brown, Hankow Brown	Hupeh, China.
1457		6710	Brill Blackhull	Chihli, China.
1576			Tokyo Brown	Honshu, Japan.
1584			Paperhull	Do.
1585			Hoki Brown	Do.
1586			Tokyo Brown	Do.
	28		(Unnamed) Brown	China.
	(152)	16792	Valley Brown	Chekiang, China.
	120	17920	Brill Blackhull	Chihli, China.
	121	17921	Hansen Brown	Do.
	122	17922 (24990)	Peesan Brown	Do.
	123	17923 (24991)	Tientsin Brown	Do.
	152	(16792)	Valley Brown	Chekiang, China.
	171	18518 {24992 24993 24994}	Manchu Brown	Manchuria.
	190	18610	Mukden White	Chihli, China.
	191	18611	Manchu Brown	Do.
	192	18612	do	Do.
		18613	Headlands Brush	Do.
		18614	Korean Brush	Do.
		18625	Meyer Brown	Do.
		18626	Chihli Brush	Do.
	193	19187	Kali Brown	Shengking, Manchuria.
	261	20612 (24995)	Manchu Brown	Manchuria.
	262	20620	do	Usuri, Siberia.
	263	20621	Paperhull	Do.
	264	20627	Manchu Brown	Manchuria.
	265	20706	Korean Brush (?)	Usuri, Siberia.
	272	21077	Mukden White	Shengking, Manchuria.
	273	21078	Valley Brown	Do.
	276	21676	Ichang Brown	Hupeh, China.
	277	21677	Tokyo Brown	Do.
	278	21678	Shasi Brown	Do.
	293	22010	Shantung Dwarf	Shantung, China.
	(327)	22011	Redstem	Do.
		22012	(Unnamed) Brown	Do.
	309	22911	Valley Brown	Kiangsu, China.
	310	22912	Barchet Blackhull	Do.
	323	23230	Chusan Brown	Chekiang, China.
	324	23231	do	Do.
	326	(6604, Kan. 595)	Hankow Brown	Kansas, U. S. A.
	327	(22011)	Redstem	Shantung, China.
	328	24478	Manchu Brown	Kirin, Manchuria.
	(122)	24990	Peesan Brown	Texas, U. S. A.
	(123)	24991	Tientsin Brown	Do.
	(171)	{24992 24993 24994}	Manchu Brown	Do.
	(261)	24995	do	Do.
	412	27553	Korean Blackhull	Chosen.
	413	27554	Choonchun Brown	Do.
	414	27555	Moose Brown	Do.
	421	28027	Ware Brown	Kiangsu, China.
	423	28057	Valley Brown	Shengking, Manchuria.
	424	28058	Parker Brown	Do.

Table III shows the localities from which these varieties of kaoliang have been introduced. These localities are grouped by provinces, under the major political division of which they are a part. For each city and town the approximate latitude and longitude are given, when the place could be found on recent maps. No attempt has been made to indicate the position more closely than by the approximate parallel and meridian.

As stated previously, it is not known whether the sample obtained in Siberia at 51° north latitude was grown there or was imported from some point in Manchuria having a more southern latitude.

TABLE III.—*Localities from which seeds of kaoliangs have been introduced, with the approximate latitude and longitude.*

Division.	Province.	Locality.	Position.	
			Latitude, N.	Longitude, E.
			Degrees.	*Degrees.*
Siberia	Trans-Baikalia	Nertchinsk	51	120
	Usuri	Vladivostok	43	132
		(Not designated)	43–50	132–140
Japan	Honshu	Tokyo	36	140
		Yokohama	36	140
Chosen (Korea)		Choonchun		
		Pingyang	39	126
Manchuria	Kirin	Harbin	46	127
	Shengking	Mukden	42	123
		Newchwang	41	122
China	Chihli	Kungkitschwang	40	116
		Peking	40	116
		Peesan		
		Shanhaikwan	40	120
		Tientsin	39	117
	Shantung	Tsou	35	117
		Chungdun	37	117
		Chingshan	37	118
	Kiangsu	Tsungming Island	32	122
	Hupeh	Hankow	30	114
		Ichang	31	112
		Wuchang	30	114
	Chekiang	Chusan Islands	30	122
		Hangchow	30	120

TESTING THE INTRODUCTIONS.

Some of the earlier introductions by the Office of Foreign Seed and Plant Introduction, as well as several lots obtained independently by the writer, were tested several years ago from the standpoint of forage production. Since it was immediately evident that the fodder was of little value they were mostly discarded after being grown but a single season. These early tests were made at the Arlington Experimental Farm of the Bureau of Plant Industry, at Arlington, Va., and many of them were duplicated at the State experiment stations at Knoxville, Tenn., Baton Rouge, La., and Hays, Kans. The writer wishes to express here his thanks to the directors of these stations and to the officers in charge of the experimental plats for their courteous and helpful cooperation in these tests. Thanks are also due to the Office of Forage-Crop Investigations, and especially to Mr. A. B. Conner, superintendent of the forage experiment station at Chillicothe, Tex., for assistance in cooperative varietal tests at that point.

Since the beginning of the year 1906 nearly all kaoliang introductions have been tested from the standpoint of grain production by the Office of Grain Investigations. As soon as an introduction has been received and given an accession (S. P. I.) number by the Office of Foreign Seed and Plant Introduction, the seed is transmitted to the writer for a test of its varietal and agronomic characters. After receiving a Grain Investigations (G. I.) number, a sample sufficient for a hundredth-acre nursery row is sent to the Amarillo experiment farm, which is the chief breeding station of the Office of Grain Investigations for grain sorghums. This farm is located only 2 miles from the town of Amarillo, in the Panhandle of Texas. The elevation is 3,600 feet, the average annual precipitation about 21 inches, the summer temperatures high, the humidity low, and evaporation rapid. These conditions are severe enough to quickly indicate undesirable sorts. The season is short enough to put varieties having early or medium maturity at a premium and yet long enough to permit a varietal study of later maturing forms.

If there is reason to believe, in advance of a test, that the introduction is especially early, the original seed is also tested the first season at one or two points in the North, such as the Bellefourche and Highmore experiment farms in South Dakota, but otherwise the preliminary test is confined to the Amarillo form.

The nursery row, grown from the original seed, is the basis of selection for future tests. If the crop proves early, with a satisfactory habit of growth and a desirable type of head, a considerable number of heads are selected for growing in head rows the following season at other points. If, as more commonly happens, the variety proves late, or of too tall a growth, or with an undesirable type of head, or a mixture of two or more forms, a limited number of heads are selected to be grown in head rows again the following season at the Amarillo experiment farm. Since the kaoliangs are likely to have a limited field of usefulness in this country, all selections are made looking toward the increase of the characters necessary to adapt the crop to the desired conditions.

These characters briefly are earliness, dwarf to medium stature, and compact to semicompact heads, well exserted and well filled. Such selection often quickly alters the nature of the variety so much along these lines that a description of the average plant from the original seed will scarcely fit the improved crop of two or three seasons later.

Table IV shows the varieties that have been under experiment during the period from 1906 to 1911, inclusive, in which the writer has been engaged in the study of sorghums from the standpoint of grain production. It will be seen that 35 introductions have been studied during the period. Of this number 10 have been discarded as undesirable, about 15 are yet on probation, and about 10 are considered as fixed types of agronomic value. Five of this last group have already been distributed to cooperating farmers, one of the oldest selections (No. 171) in considerable quantity.

TABLE IV.—*Years in which recent kaoliang introductions have been tested at the experiment farm at Amarillo, Tex.*

G. I. No.	S. P. I. No.	Years grown.						G. I. No.	S. P. I. No.	Years grown.					
120	17920	1906	1907	1908	1909	1910	1911	277	21677	......	......	......	......	......	1911
121	17921	1906	1907	......	......	......	......	278	21678	......	......	......	......	......	1911
122	17922	1906	1907	1908	1909	1910	1911	293	22010	......	......	1908	1909	1910	1911
123	17923	1906	1907	1908	1909	1910	1911	309	22911	......	......	1908	1909	1910	1911
152	16792	1906	......	1908	......	......	......	310	22912	......	......	1908	1909	1910	1911
171	18518	1906	1907	1908	1909	1910	1911	323	23230	......	......	......	1909	......	......
190	18610	......	1907	1908	1909	1910	1911	324	23231	......	......	......	1909	1910	1911
191	18611	......	1907	1908	......	......	......	326	6604	......	......	......	1909	1910	1911
192	18612	......	1907	1908	......	......	......	327	22011	......	......	......	1909	1910	1911
193	19187	......	1907	1908	1909	1910	1911	328	24478	......	......	......	1909	1910	1911
261	20612	......	1907	1908	1909	1910	1911	350	27764	......	......	......	......	1910	1911
262	20620	......	[1] 1907	......	......	......	......	412	27553	......	......	......	......	1910	1911
263	20621	......	1907	1908	......	......	......	413	27554	......	......	......	......	1910	1911
264	20627	......	[1] 1907	......	......	......	......	414	27555	......	......	......	......	1910	1911
265	20706	......	1907	1908	......	......	......	421	28027	......	......	......	......	1910	1911
272	21077	......	1907	1908	1909	1910	1911	423	28057	......	......	......	......	1910	1911
273	21078	......	1907	1908	......	......	......	424	28058	......	......	......	......	1910	1911
276	21676	......	......	......	......	......	1911								

[1] Did not germinate.

DESCRIPTIVE LIST OF INTRODUCTIONS.

The following list includes all official introductions of kaoliangs by the United States Department of Agriculture, with a single exception, so far as they are known to the writer. The exception noted is G. I. No. 28, the seed of which did not germinate. The list contains also those home-grown selections, from original introductions, which have been given new numbers. The six lots represented by Nos. 24990 to 24995 are examples of such renumberings of improved strains.

The first seven numbers described are those received independently and accessioned by the former Division of Agrostology. Then follow in numerical sequence the numerous introductions and accessions by the Office of Foreign Seed and Plant Introduction, 52 in all, making a total of 59 separate lots described. The 27 varieties herein described include 58 of the 59 lots. A single introduction, S. P. I. No. 22012, remains unidentified for lack of sufficient data.

The varieties proposed herein must be understood in the broad sense in most cases. They are group varieties rather than races or strains. From most of them it is possible to isolate strains sufficiently distinct from each other to be worthy of separate names when grown several years and fully described.

It is probable that most of the major group varieties have now been obtained and studied. Many minor forms doubtless exist in China and Chosen (Korea), which have not yet been introduced into this country. They will probably all be found to come within the limits of the group as here outlined. Most of them are likely also to fall into the group varieties as hereafter described under the classification of the kaoliangs.

In characterizing the different introductions little mention has been made of the leaves or of the awns on the lemmas or flowering glumes. The leaves are small compared with those of kafirs or of most sorgos and are more comparable in size to those of Amber sorgo and the milos. In general, the leaves are proportionate to the size and height of the culm and present no distinctive features. The same is true of the awns, which are universally present.

The terms used in describing the colors of the seeds and glumes are those by Ridgway.[1]

Very few of the many kaoliang introductions have distinctive native names, so far as is indicated by the notes accompanying the seeds. In the few cases where native names are known they are usually too long or too difficult in spelling for use as varietal names. It has therefore been necessary to choose a name for each of the 27 varieties described. The endeavor of the writer has been to apply short and simple names, as was done previously in the case of soy bean varieties,[2] and it is hoped that these names may commend themselves to agronomists and crop breeders. The second word of the double names, as White, Blackhull, Brown, etc., will doubtless be dropped in the case of varieties which finally become well known.

AGROSTOLOGY NUMBERS OF INTRODUCTIONS.

1442. *Brill Blackhull.* Received as "Blackhull White kaoliang," by Mr. Ball, from the California experiment station (No. 142–1900) in 1902; grown at the Arlington Experimental Farm in 1903. Plants 7 to 10 feet high, slender, heading in 95 days when sown May 20, and bearing large, lax, oval-oblong panicles 10 to 14 inches in length; spikelets 5.5 mm. long; seeds white, narrowly oval, 4.5 to 5 mm. long by 3 to 3.5 mm. wide, three-fourths inclosed by shining black glumes. Some plants bore panicles somewhat umbelliform, with longer drooping branches. There was also an admixture of a brown kaoliang with more compact and oblong panicles.

1443. *Mukden White.* Received as "White glutinous kaoliang" from the same source as No. 1442. Grown at the Arlington farm in 1903, only a few seeds germinating; plants 8 to 9 feet tall, heading in 94 days from seed sown on May 20; panicles lax, ovate pyramidal, 10 to 12 inches long; spikelets 4 to 6 mm. long, broadly oval; seeds 4 to 5 mm. by 3 to 3.5 mm. wide, oval or obovate oval, white, about one-third exserted; glumes 3 to 4 mm. long, firm, buff to orange buff and orange vermilion.

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[1] Ridgway, Robert. A Nomenclature of Colors for Naturalists, 1886, 129 pp., 17 pls.

[2] Ball, Carleton R. Soy Bean Varieties. Bulletin 98, Bureau of Plant Industry, U.S. Dept. of Agriculture, 1907, 30 pp., 5 pls. (Of 23 varieties described in this paper, names were made outright for 18 and simplified for 3 of the remaining 5.—C. R. B.)

1444. *Hansen Brown* (fig. 8, *a*). Received as "Red kaoliang" from the same source as No. 1442. Grown at Arlington farm in 1903, producing heads in 90 days on plants 10 feet high, bearing large, lax, oval panicles 12 to 14 inches long; spikelets 4.5 to 5.5 mm. long; seeds 4 to 5 mm. long by 3 to 4 mm. wide, obovate or oval, burnt sienna to cinnamon and buff; glumes black, shining, 4 to 4.5 mm. long.

1576. *Tokyo Brown.* Received from Hon. E. C. Bellows, consul general, Yokohama, Japan, on March 6, 1903, with the following note:

> I have the honor to transmit a package of Japanese sorghum seed, of the kind known as *morokoshi-kibi*. Messrs. L. Boehmer & Co., horticulturists, of Yokohama, who have furnished this seed without charge, inform me that this sorghum "is of very little importance in Japan, being generally planted along the borders of fields only, in order to protect the field crops against winds, etc. In some parts of the country where rice and other cereals do not grow, sorghum is, to a certain extent, cultivated as a field crop. It is sown in April in seed beds and later transplanted at intervals of 8 or 10 inches." (*Bellows.*)

Grown at Arlington farm in 1903; plants very slender, 5 to 7 feet in height, producing heads in 95 days; panicles ovate pyramidal or somewhat oval, heavy, 6 to 11 inches long; spikelets 3.5 to 4.5 mm. long; seeds 3 to 4.2 mm. by 2.8 to 3.8 mm. wide, from broadly obovate to nearly lenticular; chestnut to burnt sienna; glumes clay to vinaceous cinnamon and maroon, somewhat gibbous at the base, transversely shouldered above the middle, the apex strongly depressed, closely appressed to the seed.

1584. *Paperhull.* Received from Dr. J. Sawano, imperial experiment station, Tokyo, Japan, April 23, 1903, accompanied by the following memorandum:

> *Andropogon sorghum* Brot. var. *saccharatus* Koern. Japanese name, *sato-morokoshi* or *rozoku*. This plant was introduced into this country from China about 28 years ago. For many years we tried to prepare sugar from it in many localities, but with poor success, on account of climatic and other circumstances. At the present time it was difficult to obtain even the small quantity sent. (*Sawano.*)

Grown at Arlington farm in 1903; plants 5 to 6 feet tall with very slender stalks, producing heads in 92 days when sown May 27; panicles ovate conical, slender, 6 to 10 inches long, often one-sided and hence right-angled triangular by the bending of the peduncle; spikelets 4.5 to 5.5 mm. long; glumes black or occasionally maroon, thin, papery, equaling the seeds; seeds 3 to 4.5 mm. by 2.5 to 3.5 mm. wide, oval, russet.

1585. *Hoki Brown.* Source, the same as No. 1584.

> *Andropogon sorghum* Brot. var. *obovatus* Hack. Japanese name, *hoki-morokoshi*. Its cultivation is quite similar to that of *morokoshi* (see No. 1586); cultivated principally for the ears or top part of the plant, from which, after the seeds are thrashed out, we make brooms, so that the name *hoki*, meaning broom, is given to the plant. It is harvested when fairly, but not fully, ripe because when overripe it is too weak or brittle to be used. (*Sawano.*)

Grown at Arlington farm in 1903; sown May 27 it produced heads in 90 days. The description will be found under this variety in the chapter on classification.

1586. *Tokyo Brown.* Source same as for 1584.

> *Andropogon sorghum* Brot. var. *vulgare* Hack. Japanese name, *to-kibi*. It is generally planted along the boundary of a farm plat as a wind shelter for another principal summer crop. Its cultivation is very easy, and, indeed, the farmer does not pay much attention to it. In May or June the seeds are sown in one or two rows. It is harvested about October or November, when the heads turn yellowish in color. (*Sawano.*)

Grown at Arlington farm in 1903; plants 6 feet high, producing heads in 90 days when sown May 27 and bearing very heavy, oval panicles, 8 to 11 inches long and 4 to 5 inches wide, frequently one-sided from the bending of the stems; branches spreading or ascending; spikelets broadly obovate, 3 to 4 mm. in length; glumes brick red to maroon, otherwise as in No. 1576; seeds 3 to 4 mm. long by 2.5 to 3.7 mm. wide, broadly obovate to nearly lenticular, chestnut to blackish at the apices.

FOREIGN SEED AND PLANT INTRODUCTION NUMBERS.

225. *Hansen Brown.* Received from North China from Prof. N. E. Hansen in March, 1898. "*Ga-oo-lan*, used for human food." Not grown by the writer and no record of its habit on file; spikelets 4 to 5.2 mm. in length; glumes black, shining; seeds 3.5 to 5 mm. long by 2.5 to 3.5 mm. wide, obovate oval, exserted about one-fourth their length, walnut brown to burnt umber.

939. *Manchu Brown.* Received from Nertchinsk, Siberia, through Prof. N. E. Hansen, May 24, 1898; collected by Mr. Roborovsky. Not grown by the writer, but grown by Mr. J. E. Payne at Cheyenne Wells, Colo., in 1900. He notes that when planted April 27 it matured earlier than Early Amber sorgo; spikelets 4.5 to 5 mm. long; glumes black, shining, 3 mm. long; seeds 4 to 4.5 mm. by 3 to 4 mm., obovate oval to sublenticular, chocolate or walnut brown to buff, exserted nearly one-half.

3863 (Agrost. No. 1448). *Hansen Brown* (fig. 8, *b*). Received from China through Dr. H. W. Wiley, Chief of the Division of Chemistry, September, 1899.

"*Kao liang.*"—From 10 to 15 feet in height; growth similar to corn; stalk used for fuel and hedges; leaves stripped for fodder; grain extensively used for food and in the manufacture of alcohol.

Grown at Arlington farm in 1903; plants 10 feet in height, very late, heading in 100 days, ripening in 140 days; panicles large, lax, oblong oval or sometimes closely ovate, 12 to 14 inches long; spikelets 4.5 to 5.5 or 6 mm. long; glumes black, shining, 4 to 5 mm. long; seeds 3.5 to 5 mm. by 2.5 to 3 mm., obovate oval, bay to walnut brown.

4905 (Agrost. No. 1450). *Tokyo Brown.* Received from Wuchang, Hupeh, China. Presented by Messrs. G. D. Brill and J. W. Gilmore.

Loh goa liang (No. 38). This is a nonsaccharine sorghum. There are two or three kinds, but the main use of all is for making a kind of whisky. (*Gilmore.*)

Grown at Arlington, Va., Knoxville, Tenn., and Baton Rouge, La., in 1903. No germination obtained at Arlington and very poor germination elsewhere. Plants 1.5 to 1.8 meters (5 to 6 feet) in height, stooling freely; panicles oval, lax, large, 2.5 to 3.5 dm. (10 to 14 inches) long, the branches 1.5 dm. (6 inches) long and drooping, the apex of the panicle often nodding; spikelets 2.3 to 4 mm. long, almost spherical; glumes coriaceous, gibbous at the base, transversely ridged above the center, the apex strongly depressed and closely appressed to the seed, mostly cream buff shaded to heliotrope, to burnt sienna and claret; seeds 2.5 to 3.5 mm. by 2.5 to 3 mm., very broadly obovate or mostly sublenticular, clay to dark clay or darker, nearly included.

6406 (Agrost. No. 1453). *Baird Brush* (fig. 8, *c*). Received from Pyeng Yang (Ping-yang), Chosen (Korea), May 3, 1901. Presented by Rev. W. M. Baird.

A kind of grain similar in appearance to broom corn or sugar cane. The seeds are eaten. The canes are very straight and quite useful. Planted in May. (*Baird.*)

Grown at Arlington, Va., in 1903. Plants 1.8 to 2.7 meters (6 to 9 feet) in height; panicles slender, light colored, umbelliform, 3 to 5 dm. (12 to 20 inches) long, the apex nodding from the weight of seed; spikelets 4.5 to 6 mm. long; glumes shining, clay to tawny; seeds 4 to 5 mm. by 3 to 3.5 mm., oval, flattened, one-fourth exserted, clay to russet. A tall and medium-late variety, ripening in 120 days after planting.

6411 (Agrost. No. 1454). *Meyer Brown* (fig. 8, *d*). Source of seed same as for No. 6406.

Kind of grain similar in appearance to broom corn and sugar cane. The grain is eaten by Koreans. The canes are straight and valuable. (*Baird.*)

Grown at Arlington, Va., in 1903. Plants 1.8 to 2.4 meters (6 to 8 feet) in height, rather slender; panicles large, heavy, compact or semicompact, 1.5 to 2.5 dm. (6 to 10 inches), mostly one-sided from the leaning of the stalks and peduncle, dark red from the large and well-exserted seeds; spikelets 4 to 5.5 mm.; glumes black, shining; seeds 3.5 to 5 mm. long by 2 to 4 mm. wide, oval or obovate oval, a few sublenticular, exserted one-fourth to one-third, russet to walnut and chocolate. A variety of medium height and medium early in maturity, ripening in 120 days.

6604 (Agrost. No. 1455; also G. I. No. 326 selected from Kansas experiment station No. 595, which was grown from original seed of S. P. I. No. 6604). Hansen Brown in part; Hankow Brown in part (Pl. II, *1*). Received from Hankow, China, under the name "Barbados millet," May 17, 1901. Presented by Mr. G. D. Brill.

Grown at Arlington, Va., Knoxville, Tenn., Baton Rouge, La., and Hays, Kans., in 1903. It proved to be a decided mixture, containing the tall, late variety Hansen Brown, 2.4 to 3 meters (8 to 10 feet) in height, stout, with large leaves and large ovate or conical panicles, some lax, some more dense. It contained also one early strain of medium height which, without doubt, is the one later designated as G. I. No. 326. In 1903 the writer was concerned only with forage-producing varieties and this one was no longer grown. In 1908, however, when engaged in the study of grain-producing sorghums, he obtained from the Kansas experiment station a sample of their No. 595, which was designated as G. I. No. 326. This was ascertained to have been produced from S. P. I. No. 6604 and quite certainly represents the early strain noted in 1903. This Kansas strain was grown at Amarillo, Tex., in 1909 and may be described as follows: Plants 1.5 to 1.8 meters (5 to 6 feet) in height; panicles oval oblong, 2 to 2.7 dm. (8 to 11 inches) in length, some compact with continued rachis and also branches 6 to 10 cm. long, often naked for more than half their length; spikelets 3 to 4.5 mm. long; glumes mostly black and shining; seeds 3 to 4 mm. long by 2 to 5.3 mm. wide, obovate to broadly obovate or sublenticular, cream to burnt sienna, scarcely exserted. An early variety, maturing in 95 to 100 days from planting.

6710 (Agrost. No. 1457). *Brill Blackhull.* Received from Peking, China, June 12, 1901, through Mr. G. D. Brill (No. 156).

"This is much grown for human food around Peking and is considered much superior to the other varieties." (*Brill.*)

Grown at Arlington, Va., and Baton Rouge, La., in 1903. No germination was obtained at the former place and only three or four seeds grew at the latter. Plants 2.4 to 2.7 meters (8 to 9 feet) in height, suckering abundantly by reason of the thin stand; heads oval, lax, large, 2.5 to 3.5 dm. (10 to 14 inches) long, 2 to 2.5 dm. (8 to 10 inches) in width. Spikelets 4.5 to 6 mm. long; glumes black, shining; seeds narrowly oval to oval, 4 to 5.5 mm. long by 3 to 4 mm. wide, white. A tall and late variety, maturing in 120 to 140 days.

16792 (G. I. No. 152). *Valley Brown.* Received from Hangchow, China, December 15, 1905, through Mr. Frederick D. Cloud, American vice consul.

This bean (Black soy, No. 16796) mixed with "kaoliang" (sorghum) seed, chopped grass, or straw, with a little bran, makes the very best horse feed. Perhaps the "kaoliang" is the most highly prized of all forage plants grown in China. No part of the plant goes to waste. Two or three weeks before the plant matures and the seed is ripe the farmer strips nearly all the blades from the plant, ties them in bundles, allows them to cure in the sun for a few days, and then stacks them away indoors. All through the winter these blades are keenly relished by horses and donkeys. Then the seeds are gathered, combed out, and marketed. Several varieties of alcohol and wines are made from these seeds, and the deadly native drink "sam-shu"—at least one variety of it—is made from "kaoliang" seed. The seed makes excellent food for stock of all kinds. The long stalks are thrown on the thrashing floor, rolled flat by heavy stone rollers, carefully cleaned of all particles of pith, and woven into a great variety of mats and matting, suitable for use on floors, for window shades, or for the roofs of native houses and sheds. These stalks are also extensively used for fuel by the farming class. It is a most valuable crop and may be found throughout all the northern provinces. Not grown much as far south as Hangchow. (*Cloud.*)

Grown at Chillicothe and San Antonio, Tex., in 1906. Plants 2.1 to 3 meters (7 to 10 feet) in height, 1.5 to 2 cm. in diameter at the butt, producing 1 to 3 suckers and bearing 9 to 13 leaves, 5 to 7 cm. (2 to 3 inches) wide and 6 to 7.5 dm. (2 to 2.5 feet) long; panicles broadly oval or occasionally ovate, large, 2 to 3.5 dm. (8 to 14 inches) long, 1 to 2 dm. (4 to 8 inches) wide; spikelets obovate, 4 to 5.5 mm. long; glumes 3.5 to 4.5 mm. long, buff to tawny or claret brown; seeds 3.5 to 5 mm. long by 2.5 to 4 mm. wide, obovate oval, chestnut to russet and buff. The original introduction contained a mixture of varieties and some hybrids. The principal variety, to which the name is applied, is of medium height and medium-early maturity, ripening in 100 to 105 days.

17920 (G. I. No. 120). *Brill Blackhull* (Pl. II, *A*). Received from Peesan, China, February 23, 1906, through Mr. Frank N. Meyer, Agricultural Explorer, Bureau of Plant Industry.

This variety has white seeds and is used for making bread; as such it is more highly esteemed than the brown-colored varieties, which are generally only used as fodder for the domestic animals. (*Meyer.*)

Grown in varietal test at Amarillo, Chillicothe, and San Antonio, Tex., in 1906. Plants 2.1 to 3.6 meters (7 to 12 feet) in height, partly proportionate to locality, producing 1 to 3 suckers and bearing 10 to 15 leaves each 6 to 7.5 cm. (2.5 to 3 inches) wide and 6 to 7.5 dm. (2 to 2.5 feet) in length; panicles broadly oval, lax, heavy (weighing 3 ounces each), 2.2 to 3.5 dm. (9 to 14 inches) long and 1 to 1.5 dm. (4 to 6 inches) wide, large, much-branched, the lower branches 1.2 to 2.5 dm. (5 to 10 inches) long, flexuous at the base, equaling the rachis, or one-half to seven-tenths as long as the panicle; spikelets obovate oval, 6 to 7 mm. long; glumes black, shining, 3 to 4.5 mm. long; seeds oval or narrowly oval, white, 4 to 6 mm. long by 3 to 3.5 mm. wide, one-third exserted; anthers pale yellow and stigmas white at San Antonio. A tall, late-maturing variety, ripening seed in 120 to 135 days from planting.

17921 (G. I. No. 121). *Hansen Brown* (fig. 9, left; Pl. II, *E*). Source the same as for No. 17920.

(No. 22, *a.*) A variety with dark-brown seeds, universally used throughout North China as fodder for domestic animals. The stems of sorghum are used in building houses, the stalks being embedded in the mud walls; also for making fences, baskets, mats, tying and roofing material, and for fuel. (*Meyer.*)

Grown in varietal test at Amarillo, Chillicothe, and San Antonio, Tex., in 1906. Plants 2.1 to 3 meters (7 to 10 feet) in height, 1.5 to 2 mm. (0.5 to 0.7 inch) in butt diameter; suckers, 1 to 3; leaves, 10 to 13, 5 to 8 cm. (2 to 3 inches) wide, 6 to 7.5 dm. (2 to 2.5 feet) in length; panicles broadly oval, semicompact to lax, 2 to 3 dm. (8 to 12 inches) long and 1 to 2 dm. (4 to 8 inches) wide; spikelets 5.5 to 6 mm. long; glumes black, shining, 4 mm. long; seeds 4.5 to 5.5 mm. long by 3.5 to 4.5 mm. wide, bay to cinnamon, one-half exserted. A tall and late variety, maturing in 125 to 140 days.

17922 (G. I. No. 122). *Peesan Brown* (Pl. II, *N*). Source the same as for No. 17920.

(No. 23, *a.*) A variety with light-brown seeds, not very much grown. It is used where found as a fodder plant and also for making a brown-colored kind of bread. (*Meyer.*)

Grown in varietal test at Amarillo, Chillicothe, and San Antonio, Tex., in 1906, and at different points continuously thereafter. Plants 2 to 2.4 meters (6.5 to 8 feet) in height; suckers, 1 to 3; leaves, 9 to 11, 5 to 7 cm. (2 to 2.6 inches) wide, 4.5 to 6 dm. (1.5 to 2 feet) in length; panicles erect, well exserted, ovate conical or frequently one-sided by the bending of the peduncle, 1.5 to 2.8 dm. (6 to 11 inches) long, 1 to 1.5 dm. (4 to 6 inches) wide; spikelets oval, 4 to 5.5 mm. long; glumes 3.5 to 4.5 mm. long, clay to madder brown; seeds 3.5 to 5 mm. long by 3 to 4 mm. wide, mostly oval or some broadly obovate, russet to bay in the original sample, becoming cream buff to raw sienna and hazel in later years. A variety of medium-late maturity, ripening in 115 to 125 days. The strain under selection, G. I. No. 122, is about 5.5 feet in height and matures in 110 to 115 days.

17923 (G. I. No. 123); 24991. *Tientsin Brown* (fig. 9, right; Pl. II, *F*). Received from Tientsin, Chihli, China, through Mr. F. N. Meyer, February 23, 1906.

(No. 151, *a*.) A superior variety of sorghum which grows from 15 to 20 feet in height. The grain is ground, and from the flour a good kind of bread is made; is used also for the same purpose as the one described under No. 22, *a* (S. P. I. No. 17921). In addition to this the leaves are pulled off before they have turned brown, when they make an excellent cattle food, either fresh or dry. The roots are also dug and used as fuel. (*Meyer.*)

Grown in varietal test at Amarillo, Chillicothe, and San Antonio, Tex., in 1906, and at various points in 1907. A variety of medium height and maturity, ripening in 105 to 120 days. The large heads are not well filled at the base. It differs from Hansen Brown chiefly in being earlier. A description will be found under this variety in the classification.

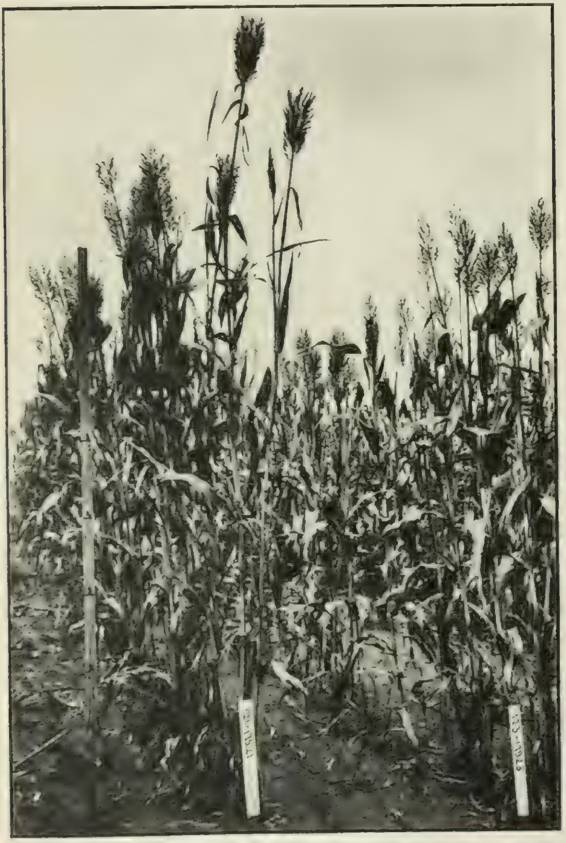

FIG. 9.—Plants of two brown kaoliang varieties, Hansen Brown (G. I. No. 121, S. P. I. No. 17921), and Tienstin Brown (G. I. No. 123, S. P. I. No. 17923), grown from original seed at Chillicothe, Tex., September 6, 1906. (Photographed by C. R. Ball.)

18518 (G. I. No. 171); also 24992, 24993, and 24994. *Manchu Brown* (fig. 10; Pl. II, *H*). Received from Manchuria through the Yokohama Nursery Co., Yokohama, Japan, May 9, 1906.

Kaulien sorghum of Manchuria, which forms the staple produce of that country and which has been made famous in the last year. It grows 8 to 10 feet high; the stalks and grain were indispensable for all concerned. (*Yokohama Nursery Co.*)

Grown in varietal test at Amarillo, Chillicothe, and San Antonio, Tex., in 1906, at various points in 1907, and in our regular field experiments each year thereafter. Plants low, 1.4 to 1.8 meters (4.5 to 6 feet) in height, .6 to 1 cm. (.25 to .40 of an inch) in butt diameter; suckers 1 to 3; leaves 7 to 9, small, 4 to 6 cm. (1.5 to 2.5 inches) wide, 3 to 4.5 dm. (1 to 1.5 feet) long; panicle well exserted, oval, 2 to 2.5 dm. (8 to 10 inches) long, the lower branches 5 to 10 cm. (2 to 4 inches) in length; rachis continuous; spikelets 4.5 to 6 mm. long; glumes black, shining; seeds obovate oval to oval, 4 to 5.5 mm. long by 3 to 4 mm. wide, walnut brown to burnt sienna or madder brown where exposed, and white to buff and russet where included in the glumes, one-third exserted; anthers and stigmas yellow. A low, early, and valuable variety, ripening in 90 to 100 days. Widely distributed to cooperating farmers at higher elevations in the central Plains area.

18610 (G. I. No. 190). *Mukden White* (fig. 11; Pl. II, *D*). Received from Shanhai-kwan, Chihli, China, at the Plant Introduction Garden, Chico, Cal., from Mr. F. N. Meyer, May 18, 1906.

(No. 153, *a*.) A white-grained variety of sorghum grown on rather alkaline land. (*Meyer*.)

Grown at Amarillo and Chillicothe, Tex., Modesto, Cal., and North Platte, Nebr., in 1907. Plants 1.5 to 2.4 meters (5 to 8 feet) in height, rather stout, 1.2 to 2.5 cm. (0.5 to 1 inch) in butt diameter, mostly without suckers; leaves 8 to 11; panicles oval or ovate, rather heavy, 2 to 2.7 dm. (8 to 11 inches) in length, basal branches 1 to 1.5 (4 to 6 inches) long; spikelets broadly oval, 5 to 6 mm. long; glumes 3 to 4 mm. long, buff, shading strongly to orange buff and orange vermilion; seeds obovate oval, 4 to 5 mm. long by 3 to 3.5 mm. wide, white, one-third exserted. A medium-tall variety, medium early to medium late in maturity, ripening in 105 to 115 days. One early head was noted as having deciduous spikelets, an unusual character which belongs to the wild species *Andropogon halepensis* Brot.

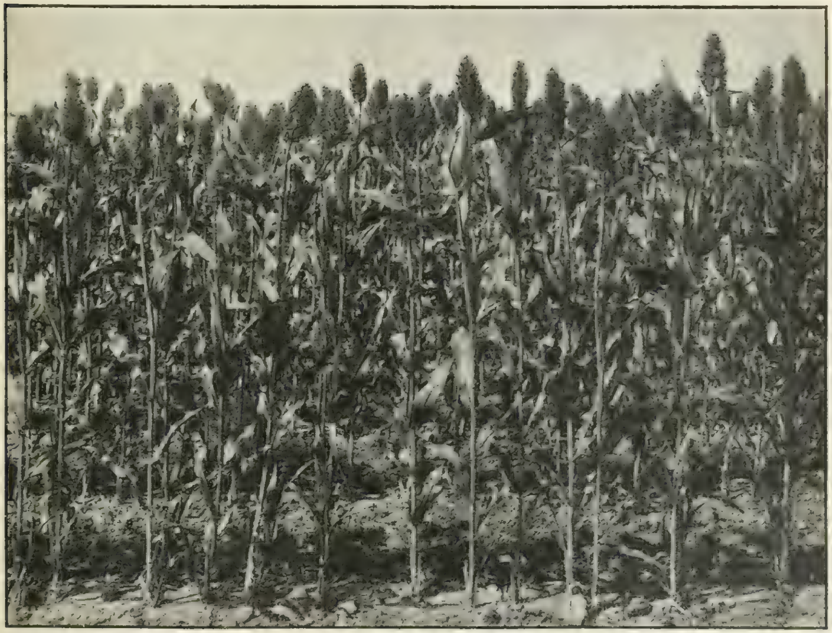

FIG. 10.—Field of Manchu Brown kaoliang (G. I. No. 171, S. P. I. No. 18518), 5 feet tall, Amarillo, Tex., August 20, 1908. (Photographed by C. R. Ball.)

18611 (G. I. No. 191). *Manchu Brown.* Source same as for 18610.

(154, *a.*) A light-brown colored variety of sorghum grown on rather alkaline land. (*Meyer.*)

Grown in varietal test at Amarillo and Chillicothe, Tex., Modesto, Cal., and North Platte, Nebr., in 1907. Plants 1.5 to 2.1 meters (5 to 7 feet) in height, slender to stout; panicle small, oval, rather compact, 1.5 to 2.2 dm. (6 to 9 inches) in length, the lower branches 5 to 10 cm. (2 to 4 inches) long, the rachis five-sixths as long as the panicle; spikelets 4 to 5.5 mm. long; glumes black, shining; seeds obovate to broadly obovate oval, 3.5 to 5 mm. long by 3 to 4 mm. wide, burnt sienna to cinnamon rufous to buff. A low to medium variety with small panicles, ripening in 100 to 105 days.

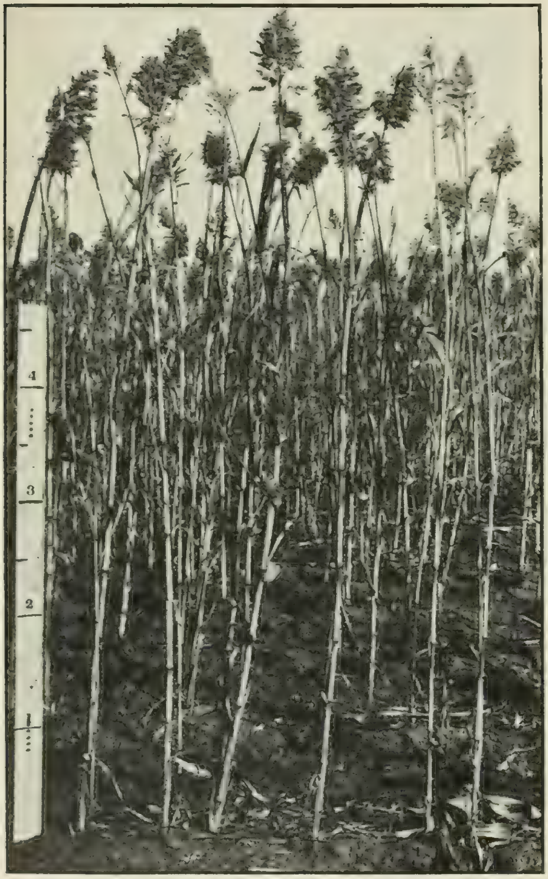

FIG. 11.—Plants of Mukden White kaoliang (G. I. No. 190, S. P. I. No. 18610), Amarillo, Tex., October 5, 1908. (Photographed by C. R. Ball.)

18612 (G. I. No. 192). *Manchu Brown.* Source the same as for No. 18610.

(155, *a.*) A dark-brown colored variety of sorghum grown on rather alkaline land. (*Meyer.*)

Grown at Amarillo and Chillicothe, Tex., Modesto, Cal., and North Platte, Nebr., in 1907. Plants slender, 1.5 to 2.1 meters (5 to 7 feet) in height; panicles medium size, light weight, lax, 2 to 2.7 dm. (8 to 11 inches) long; spikelets oval, 5 to 6 mm. long; glumes black, shining; seeds narrowly oval to oval or obovate, 4 to 6 mm. long, 2.5 to 4 mm. wide, russet to burnt umber and bay, one-third exserted. A low to medium variety, of medium early maturity, ripening in 100 to 105 days.

18613. *Headlands Brush.* Received from Peking, China, at the Plant Introduction Garden, Chico, Cal., through Mr. F. N. Meyer, May 18, 1906.

(No. 172, *a.*) White seeded. Given to me by Mr. J. T. Headlands, of the Methodist Mission, Peking. This is the drooping variety used to make brooms from. (*Meyer.*)

Grown at Chico, Cal., in 1906, but no record of its habit available. Planted at Chillicothe, Tex., in 1907, but the seed did not germinate. A description of the original panicle will be found under this variety in the classification.

18614. *Baird Brush.* Source the same as for 18613. "(No. 172, *a*.) Brown seeded."

Grown at Chico, Cal., in 1906, but no record is available. Grown at Chillicothe, Tex., in 1907. Plants slender, 2.4 meters (8 feet) in height; panicles subumbelliform, 3 to 3.7 dm. (12 to 15 inches) in length, lower branches 1.2 to 2 dm. (5 to 8 inches) long, and the rachis one-half to three-fourths as long as the panicle; spikelets 4.5 to 6 mm. long; glumes 4 to 5 mm. long, buff-yellow to burnt sienna; seeds obovate, obovate oval, or oval, 4 to 5.5 mm. long by 3 to 3.5 mm. wide, buff yellow and burnt sienna to bay, one-fifth to one-fourth exserted. A variety of medium height and of medium late maturity.

18625. *Meyer Brown.* Received from Kungkitschang, Chihli, China, at the Plant Introduction Garden, Chico, Cal., through Mr. F. N. Meyer, May 18, 1906. "(No. 171, *a*.) Red seeded."

Grown at Chico, Cal., in 1906, but no record available. Grown at Chillicothe, Tex., in 1907. Plants 2.4 meters (8 feet) in height; panicles sparse and rather slender, 2.5 to 3 dm. (10 to 12 inches) in length, the lower branches 5 to 12 cm. (2 to 5 inches) long, and the rachis two-thirds as long as, to equaling, the panicle; spikelets oval, 4.5 to 6 mm. long; glumes seal brown or black; seeds oval or obovate, 4 to 5.5 mm. long by 2.8 to 3.8 mm. wide, russet to bay. A variety of medium height and medium-late maturity, ripening in 115 days.

18626. *Chihli Brush.* Source the same as for 18625. "(No. 171, *a*.) White seeded."

Grown at Chico, Cal., in 1906, but no record available. Grown at Chillicothe, Tex., in 1907. A description will be found under this variety in the classification.

19187 (G. I. No. 193). *Kali Brown* (Pl. II, *G*). Received from Newchwang, Manchuria, through Mr. F. N. Meyer, August 28, 1906.

(No. 259, *a*) Chinese name, *kauliang*. A brown-colored variety of sorghum, said to be grown on the rather alkaline lands around Newchwang. (*Meyer*.)

Grown in varietal test at Amarillo and Chillicothe, Tex., Hays, Kans., North Platte, Nebr., Highmore, S. Dak., and Modesto, Cal., in 1907. A description will be found under this variety in the classification. A low to medium variety, early to medium early in maturity, ripening in 100 to 110 days. Differs from Manchu Brown chiefly in greater height and later maturity. Name suggested by its reported use on alkaline soils.

20612 (G. I. No. 261); also 24995. *Manchu Brown* (fig. 12). Received from Manchuria through Prof. N. E. Hansen, Agricultural Explorer, March, 1907.

(No. 92) *Gaolan.* Brought by a Russian student-soldier from Manchuria after the Russo-Japanese War. (*Hansen*.)

Grown at Amarillo, Tex., in 1907. Plants slender, 1.2 to 1.8 meters (4 to 6 feet) in height; leaves small, 7 to 10; panicles small to medium, sparse, of light weight, narrowly ovate or conical, 1.5 to 2.5 dm. (6 to 10 inches) in length, the lower branches 5 to 10 cm. (2 to 4 inches) long; spikelets 5 to 6 mm. long; glumes black, shining; seeds oval or obovate oval, 4 to 5.5 mm. long by 3 to 4 mm. wide, burnt umber to raw umber to buff, one-fourth exserted. A low and extra-early variety, maturing in 85 to 95 days, the earliest of any introduction yet tested. It is proving of value in extending the cultivation of this crop to South Dakota and other Northern and Northwestern States.

20620 (G. I. No. 262). *Manchu Brown* (?). Received from Usuri Province, Siberia, through Prof. N. E. Hansen, Agricultural Explorer, March, 1907.

(No. 100) *Gaolan.* This variety grows from 20 to 25 feet in height, and during the Russo-Japanese war the Cossacks on horseback found trouble in getting through the sorghum fields, as they would be lost from view even with their spears. (*Hansen*.)

Planted at Amarillo, Tex., in 1907, but no seed germinated. Plant not known and identification doubtful; spikelets 4 to 5.5 mm.; glumes chestnut to maroon, shining; seeds obovate or obovate oval, 4.5 mm. long by 3 to 3.8 mm. wide, walnut brown to bay.

20621 (G. I. No. 263). *Paperhull.* Source same as for No. 20620.

(No. 101) *Gaolan.* For description see No. 100 (S. P. I. No. 20620). The head does not appear as compact as in No. 100. Seed brought from Manchuria by a Russian student-soldier after the Russo–Japanese war. (*Hansen.*)

Grown at Amarillo, Tex., in 1907, and again in 1908. Plants 1.5 to 2 meters (5 to 6.5 feet) in height; leaves 6 to 8; panicle ovate or ovate conical, sparse, lax, of light weight; spikelets 4.5 to 5.5 mm. long; glumes thin, papery, black, shining, equaling the seed; seeds narrowly oval, 4 to 5 mm. long by 2.5 to 3 mm. wide, burnt umber, included. A low variety of extra-early to early maturity, ripening in 85 to 95 days; heads, however, of poor quality and the variety discarded.

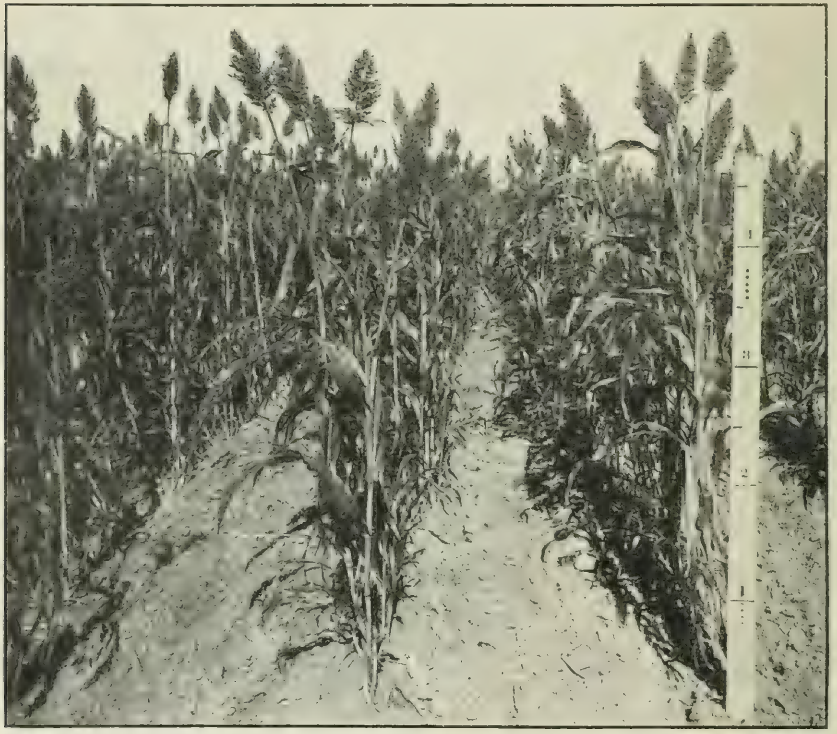

FIG. 12.—Field of an extra-early variety of Manchu Brown kaoliang (G. I. No. 261, S. P. I. No. 20612), Amarillo, Tex., August 20, 1908. (Photographed by C. R. Ball.)

20627 (G. I. No. 264). *Manchu Brown*(?). Source same as for No. 20612.

(No. 107) Native name, *Tjie-choo-meed-zha.* This variety is used for brooms in Manchuria. Seed brought from Manchuria by a Russian student-soldier after the Russo-Japanese war. (*Hansen.*)

Planted at Amarillo, Tex., in 1907, but no seed germinated. Plant not known and identification doubtful; spikelets 4.5 to 5.5 mm. long; glumes maroon to black with buff trimmings; seeds obovate oval, 4 to 4.5 mm. long by 3 to 3.5 mm. wide, walnut brown to chocolate.

20706 (G. I. No. 265). *Baird Brush* (?). Received from the southern part of the Pacific coast section of Usuri Province, Siberia, through Prof. N. E. Hansen, Agricultural Explorer, March, 1907.

"(No. 186) *Gaolan*." (*Hansen*.)

Grown at Amarillo, Tex., in 1907, when only a single seed germinated, and again in 1908. Plant 1.5 to 1.8 meters (5 to 6 feet) in height; leaves 7 to 8; panicles narrowly ovate or conical, small, lax, poorer than those of No. 20621 and much inferior to those of No. 20612; the very immature original sample has spikelets 4.5 to 5 mm. long; glumes buff to coral to madder brown; seeds too shrunken for accurate measurement; apparently no home-grown samples preserved. A low and early variety, ripening in 85 to 95 days; of no value.

21077 (G. I. No. 272). *Mukden White* (see fig. 14, *d*). Received from Mukden, Manchuria, through Mr. Frank N. Meyer, June 21, 1907.

(No. 717, *a*, January 23, 1907.) A white sorghum; Chinese name, *Pai kau liang*. The best variety of white millet grown around Mukden. It is used as a food in the form of porridge, small cakes, and also served often as vermicelli. It commands one-third more money than the brown-colored millets do. (*Meyer*.)

Grown at Chillicothe, Tex., in 1907, and at Amarillo, Tex., Hays, Kans., Akron, Colo., Bellefourche, S. Dak., and Dickinson, N. Dak., in 1908. Plants 1.8 to 2.4 meters (6 to 8 feet) in height; leaves 9 to 11; panicles large, oval to conical, lax, 2.2 to 3 dm. (9 to 12 inches) in length; spikelets oval, 4 to 5 mm. long; glumes 3 to 4 mm. long, mostly buff, rarely shaded; seeds oval to obovate oval, 4 to 4.5 mm. long by 3 to 3.5 mm. wide, one-fourth to one-third exserted. A variety of medium height and of medium-early to medium-late maturity, ripening in 95 to 115 days; panicles less desirable than those of No. 17920.

21078 (G. I. No. 273). *Valley Brown* (fig. 14, *a*). Source same as for No. 21077.

(No. 718, *a*, January 23, 1907.) A brown-colored sorghum; Chinese name *kau liang*. The best variety of brown millet grown around Mukden. It is used as a food in the shape of porridge and cakes; also an important food for the domestic animals. (*Meyer*.)

The record for this introduction is a duplicate of that for No. 21077. They were introduced, distributed, and tested together and gave identical results, the chief difference apparent in the field being in the color of the seeds; spikelets 4.5 to 5.7 mm. long; glumes buff to burnt sienna; seeds oval, broadly oval or obovate, 3.5 to 5.2 mm. long by 2.5 to 3.5 mm. wide, clay to burnt sienna, one-fourth exserted.

21676 (G. I. No. 276). *Ichang Brown*. Received from Ichang, Hupeh, China, through Mr. E. H. Wilson, collector for the Arnold Arboretum, Jamaica Plain, Mass., in November and December, 1907.

(No. 260.) A cereal growing 6 to 12 feet high. Pellicles reddish black. Cultivated in the valleys and low hills to the south of Ichang. (*Wilson*.)

Grown at Amarillo, Tex., in 1911. A description will be found in the classification. A variety of medium height and medium maturity, ripening in 110 days in the season tested.

The original sample contained some smaller spikelets with glumes gibbous at the base and transversely ridged, orange vermilion in color, apparently the same as those comprising most of No. 21677. When grown, the resulting plants were essentially Tokyo Brown, the variety represented by the above number, which is discussed below.

21677 (G. I. No. 277). *Tokyo Brown* (Pl. II, *P*). The source is the same as for No. 21676.

(No. 260, *a*.) A cereal growing 6 to 12 feet high. Pellicles black or nearly so. Commonly cultivated in the valleys around Ichang. (*Wilson*.)

Grown at Amarillo, Tex., in 1911. Plants 1.3 to 1.7 meters (4.5 to 5.5 feet) in height, with stout culms, 2.2 to 2.7 cm. (0.9 to 1.2 inches) in butt diameter; leaves 11 to 12 in number, 0.85 to 1 dm. (3.5 to 4 inches) wide, 7.5 to 8.1 dm. (2.5 to 2.7 feet) long; panicles large, conical, lax, 3 to 3.7 dm. (12 to 15 inches) in length, exserted 5 cm. (2 inches) or less, lower branches 1 to 2 dm. (4 to 8 inches) long; spikelets small, broadly ovate, 3 mm. wide in one plane, 4 mm. wide in the other, and 4 mm. long; glumes gibbous at the base, transversely shouldered above the center, apex depressed and appressed to the seed, cinnamon, cream, and clay to claret brown and black; seeds broadly obovate to sublenticular, 3 to 3.5 mm. wide by 4 mm. long, russet to burnt umber in the original seed, cream to raw sienna and burnt sienna in the Amarillo seed. A low variety of medium maturity, ripening in 110 days in the single test so far made. The original was a mixture of two varieties, the one described below and one with normal glumes, practically identical with Tokyo Brown, G. I. No. 276, from the same source.

21678 (G. I. No. 278). *Shasi Brown* (Pl. II, *M*). Source same as for No. 21676.

(No. 202.) A cereal growing 8 to 12 feet high. Pellicles dull red or reddish chestnut. Widely cultivated on the alluvial flats between Shasi and Yochow, and more especially around Shasi. It was from the last-named place that the seeds were obtained. In this part of the Yangtze Valley the sole use of sorghum (kaoliang) is for making wine and spirits. I can find no record of its being used for food even, by the peasants. (*Wilson.*)

Grown at Amarillo, Tex., in 1911. A description will be found in the chapter on classification. A variety of medium stature and maturity, ripening in 110 days in the single test made.

22010 (G. I. No. 293). *Shantung Dwarf* (fig. 13; fig. 14, *b;* Pl. II, *R*). Received from Chingshan, Shantung, China, at the Plant Introduction Garden, Chico, Cal., through Mr. Frank N. Meyer, February 12, 1908.

(No. 810,*a*, August 12, 1907.) Chinese name, *Chi tse ya tse.* A very rare dwarf variety of sorghum, not growing higher than 3 feet and making dense heads. Grows on shallow sterile soils and matures much earlier than the taller growing varieties. May do well in the semiarid regions of the western United States. (*Meyer.*)

Grown at Amarillo, Tex., in 1908, and continuously there and at other points thereafter. Description will be found under this variety in the classification. A very dwarf variety of medium-early maturity, ripening in 105 to 110 days.

22011 (G. I. No. 327). *Redstem.* Received from near Chufoo (Tsou[1]), Shantung, China, at the Plant Introduction Garden, Chico, Cal., through Mr. Frank N. Meyer, February 12, 1908.

(No. 811, *a*, September 7, 1907.) A red-stemmed variety used in the manufacture of mattings, of which pretty specimens may be seen once in a while. (*Meyer.*)

Grown at Chico, Cal., in 1908, but no record is available. Grown at Amarillo, Tex., in 1909, and thereafter. A description will be found under this variety in the classification. A low to medium variety of early maturity, ripening in about 95 days; strikingly characterized by the reddish stems.

22012. Variety not determined. Received from near Chungdun, Shantung, China; otherwise same as No. 22010.

(No. 812,*a*, September 29, 1907.) A very tall-growing loose-headed variety of sorghum. The thrashed-out heads are utilized in broom manufacture. Stands alkali well. (*Meyer.*)

Not grown by the writer and a description of the plant is not available; panicle sparse, lax, narrowly ovate conical, 4 dm. (16 inches) in length, somewhat resembling that of Minnesota Amber sorgo; branches 1.5 to 2 dm. (6 to 8 inches) long; rachis continuous; spikelets obovate oval, 5 to 5.5 mm. long; glumes 4.5 to 5 mm. long, subglaucous, smoke gray or heliotrope; seeds oval, 4.5 to 5 mm. long by 3 to 3.5 mm. wide, clay to burnt umber.

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[1] Mr. S. C. Stuntz, of the Office of Foreign Seed and Plant Introduction, identifies the Chufoo of Mr. Meyer's notes as Tsou, the suffix "foo" or "fu" merely denoting a town of certain official rank.

22911 (G. I. No. 309). *Valley Brown* (fig. 14, *c*; Pl. II, *J*.). From Tsungming Island, China. Obtained through Rev. J. Ware and presented by Dr. S. P. Barchet, interpreter, American consulate, Shanghai, China. Received May 20, 1908.

Grown at Amarillo, Tex., in 1908. Plant 1.8 meters (6 feet) in height and stoutish, 2 to 2.5 cm. (1 inch) in butt diameter; leaves 8 to 10 in number, 7.5 to 8.5 dm. (3 to 3.5 inches) wide, 6 to 6.5 dm. (2 to 2.2 feet) long; panicles oval, lax, heavy, 2 to 3 dm. (8 to 12 inches) long and 1 to 2 dm. (4 to 8 inches) wide, well exserted; spikelets 4 to 5.5 mm. long; glumes mostly buff or clay, shading to cardinal and maroon; seeds broadly obovate oval to sublenticular or subspherical, being less flattened than most, 3.5 to 5 mm. long by 2.6 to 4 mm. wide, clay to walnut brown in the original sample, cream to russet to burnt umber in later years. A low to medium variety, early to medium-early in maturity, ripening in 100 to 105 days; of considerable promise as a grain producer.

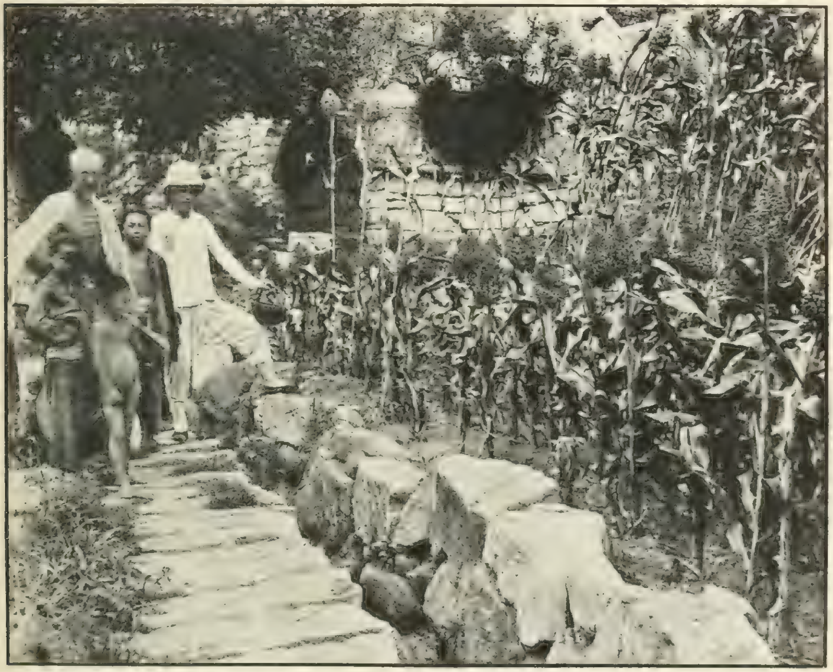

FIG. 13.—Plants of Shantung Dwarf Brown kaoliang (G. I. No. 293, S. P. I. No. 22010) in the foreground and the ordinary taller variety behind it, Chingshan, Shantung, China, August 12, 1907. (Photographed by Frank N. Meyer.)

22912 (G. I. No. 310). *Barchet Blackhull* (fig. 15; Pl. II, *C*). From Tsungming Island, China. Obtained through Rev. J. Ware and presented by Dr. S. P. Barchet, interpreter, American consulate, Shanghai, China. Received May 20, 1908.

The white variety (S. P. I. No. 22912) is considered inferior to the red (S. P. I. No. 22911, Brown), though planted in the same way. It is planted in richly manured land in rows 6 inches wide covered lightly with half an inch of earth. If plants come up too thick or crowded, the plants which should be removed are not pulled, but cut off with a sharp knife, so as not to disturb the roots of neighboring plants. (*Barchet.*)

Grown at Amarillo, Tex., in 1908, and thereafter. A description will be found under this variety in the classification. A low variety of early to medium-early maturity, ripening in 100 to 105 days; unfortunately allowed to hybridize with a brown-seeded variety in 1908, the crop of 1909 containing 50 per cent or more of hybrids. A pure strain has been isolated and is likely to prove one of the most valuable of the introductions.

23230 (G. I. No. 323). *Chusan Brown.* Received from Chusan Islands, Chekiang, China, through Mr. Frank N. Meyer, Agricultural Explorer, and brought by him to the Plant Introduction Garden, Chico, Cal., June, 1908. Forwarded to Washington, D. C., and received July 6, 1908.

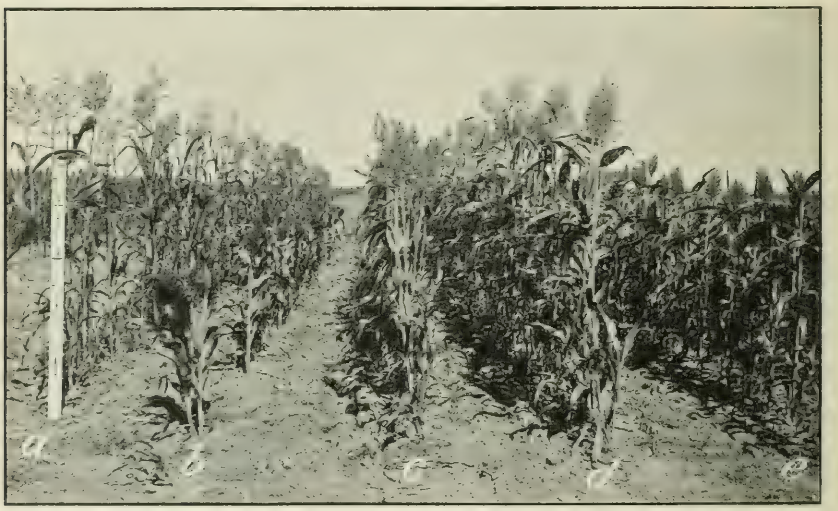

FIG. 14.—Rows of five varieties of kaoliang, Amarillo, Tex., August 20, 1908: *a*, Valley Brown (G. I. No. 273, S. P. I. No. 21078); *b*, Shantung Dwarf Brown (G. I. No. 293, S. P. I. No. 22010); *c*, Valley Brown (G. I. No. 309, S. P. I. No. 22911); *d*, Mukden White (G. I. No. 272, S. P. I. No. 21077); *e*, Barchet Blackhull (G. I. No. 310, S. P. I. No. 22912.)

(No. 983,*a*, April, 1908.) A tall-growing variety of sorghum, coming from the Chusan Islands, called *Chang tsun.* Obtained from Dr. S. P. Barchet at Shanghai, China. (*Meyer.*)

Grown at Amarillo, Tex., in 1909, where only 13 seeds germinated, each producing two stalks. No description of the plant is available; glumes short, chestnut to bay, shining; seeds broadly ovate or sublenticular, 3 to 4 mm. long by 2.5 to 3.5 mm. wide, chocolate to burnt umber to bay.

23231 (G. I. No. 324). *Chusan Brown* (Pl. II, *O*). Source same as for No. 23230.

(No. 984,*a*, April, 1908.) A dwarfy form of a sorghum, coming from the Chusan Islands, called *Tuan tsun.* Obtained from Dr. S. P. Barchet at Shanghai, China. (*Meyer.*)

Grown at Amarillo, Tex., in 1909, 1910, and 1911, only 54 seeds germinating in the first year. Plants 1.3 to 2 meters (4.5 to 6.5 feet) in height, mostly without suckers; leaves 9 to 11 in number, 0.8 to 1 dm. (3.2 to 4 inches) wide, 6.5 to 7.5 dm. (2.2 to 2.5

feet) long; panicles small, compact, 1.4 to 1.8 dm. (5.5 to 7.5 inches) long; lower branches only 5 to 9 cm. in length, seeded to the base; rachis continuous; spikelets 3.5 to 4 mm. long; glumes brick red to maroon and darker, shining; seeds broadly obovate to sublenticular, 3 to 4 mm. long by 2.8 to 3.2 mm. wide, walnut brown to bay in original sample; clay to raw sienna to bay. A low variety of medium maturity, ripening in about 110 days in 1910 and 1911.

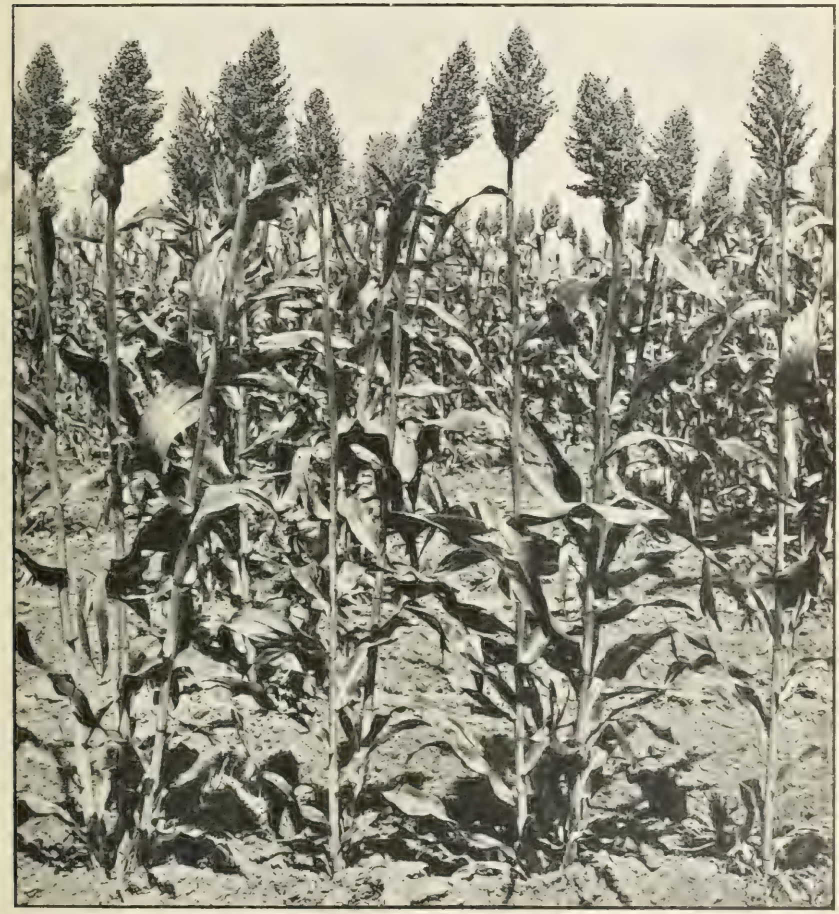

FIG. 15.—Plat of Barchet Blackhull kaoliang (G. I. No. 310, S. P. I. No. 22912), grown at Dalhart, Tex., 1911; height, 4½ feet. (Photographed by C. R. Ball.)

24478 (G. I. No. 328). *Manchu Brown.* Received from Manchuria, through Prof. N. E. Hansen, Agricultural Explorer, December 3, 1908.

(No. 85.) Variety *Gaolan* from the Harbin district, bought in a Chinese bazaar at Station Manchuria, the first station in Chinese territory going east on the Siberian Railway. The favorite variety in northern Manchuria. (*Hansen.*)

Grown at Amarillo, Tex., in 1909, and thereafter. Plants 1.4 to 1.8 meters (4.5 to 6 feet) in height, with no suckers and an average of 10 leaves; panicles oval, 2 to 2.7 dm. (8 to 11 inches) in length, lower branches 5 to 10 cm. (2 to 4 inches) long, rachis continuous; spikelets 4.5 to 5 mm. long; glumes black, shining; seeds obovate, oval, or a few broadly obovate, 4 to 5 mm. long by 3 to 3.7 mm. wide, burnt umber with chocolate tips. A low, extra-early to early variety, ripening in 80 to 90 days.

24990 (G. I. No. 122). *Peesan Brown.*

Grown on the experiment farm at Amarillo, Tex., by Mr. John F. Ross, season of 1908. Received March, 1909.

Improved by selection for dwarf stature, productiveness, etc., from S. P. I No. 17922, by Mr. Carleton R. Ball.

24991 (G. I. No. 123). *Tientsin Brown.*

Grown as was No. 24990. Improved at the last by selection from No. 17923.

24992 (G. I. No. 171, *A*). *Manchu Brown.*

Grown as was No. 24990. Improved at the last by selection from No. 18518.

24993 (G. I. No. 171, *B*). *Manchu Brown.* Record the same as for No. 24992.

24994 (G. I. No. 171, *C*). *Manchu Brown.* Record the same as for No. 24992.

24995 (G. I. No. 261). *Manchu Brown.* Grown as was No. 24990.

Improved by Mr. Carleton R. Ball, by selection from No. 20612.

27553 (G. I. No. 412). *Korean Blackhull* (Pl. II, *B*). Received from Choon Chun, Chosen (Korea) April 4, 1910, through Mr. J. Robert Moose.

Grown at Amarillo, Tex., in 1910 and 1911. A description will be found under this variety in the classification. A tall, medium-early variety with large ovate-conical heads, maturing in 103 and 108 days in the two seasons tested.

27554 (G. I. No. 413). *Choonchun Brown* (Pl. II, *Q*). Source same as for 27553.

Grown at Amarillo, Tex., in 1910 and 1911. A description will be found under this variety in the classification. A low variety of medium-early maturity, ripening in 103 and 98 days in the two seasons grown; not promising.

27555 (G. I. No. 414). *Moose Brown.* Source same as for 27553.

Grown at Amarillo, Tex., in 1910 and 1911. A description will be found in the classification. A variety of medium height and of medium-late maturity, ripening in 114 and 120 days in the two seasons tested.

28027 (G. I. No. 421). *Ware Brown* (Pl. II, *K*). Received from Tsungming Island, Chekiang, China, May 20, 1910. Secured by Rev. James Ware, of the Foreign Christian Missionary Society, Shanghai, China, and forwarded through Mr. Amos P. Wilder, American consul general.

Kowliang. Said to be the finest variety on the island. Tsungming is an alluvial island in the estuary of the Yangtze River. It lies between 31° and 32° north latitude. Prevailing winds from southeast. Total length from east to west 60 miles; average breadth 12 miles. The soil is rich except at the northwest corner, where it is overcharged with alkali. Population, including small islands around and a few towns on the north mainland, 1,200,000. (*Ware.*)

Grown at Amarillo, Tex., in 1910 and 1911. A description will be found in the classification. A medium-low and early to medium-early variety, ripening in 92 days in 1910 and in 92 to 110 days in 1911.

28057 (G. I. No. 423). *Valley Brown.* Received from Mukden, Manchuria, June 2, 1910. Produced by Mr. Edward C. Parker, agriculturist, Bureau of Agriculture, Industry, and Commerce, Mukden, Manchuria.

High stalk, spreading panicle. Chinese name, *Sungma kaoliang.* This plant is the chief and characteristic crop of Manchuria. Its seeds are the every-day food of most of the common people, as well as the chief food of the farm animals. The leaves are stripped off the plant for live-stock food, and the stalks are burned to boil the water and heat the mud houses for all Manchuria. This sample of seed comes from

Mukden, Manchuria, 42° north latitude, and is of a tall-growing variety with open or spreading panicle. This tall kaoliang thrives best in latitude 38° to 42° north, maturing usually in October and requiring a late autumn to properly mature. It withstands drought and hot, drying winds better than maize and will also stand an excess of moisture better than maize. The stalks are fibrous and rigid and do not lodge under stress as easily as maize. (*Parker.*)

Grown at Amarillo, Tex., in 1910 and 1911. Plants 2.1 to 2.7 meters (7 to 9 feet), slender to medium in diameter; leaves 9 to 10 in number, 0.7 to 0.9 dm. (2.7 to 3.5 inches) wide, 6 to 6.7 dm. (2 to 2.2 feet) long; panicle very lax, oval or subconical or sometimes nearly one-sided, large, 2.5 to 3.5 dm. (10 to 14 inches) in length, exserted 0.7 to 1.5 dm. (3 to 6 inches), with lower branches 1.2 to 2 dm. (5 to 8 inches) long, and upper branches 1 to 1.2 dm. (4 to 5 inches) or longer; the rachis one-half to three-fourths as long as the panicle; spikelets 4.5 to 5 mm. long; glumes buff to clay to hazel to brick red; seeds oval to obovate, 4 to 4.8 mm. long by 3 to 3.5 mm. wide, cream to orange buff, russet and madder brown, in 1910 white, buff, hazel, and brick red, in 1911 buff to chestnut, one-sixth exserted. A medium-early variety of medium height, ripening in 99 and 110 days in the two seasons tested.

28058 (G. I. No. 424). *Parker Brown* (Pl. II, *L*). Source same as for 28057.

Short stalk, compact panicle. Chinese name, *Chinma kaoliang.* This species matures somewhat earlier than the tall variety (S. P. I. No. 28057) and is grown commonly in Manchuria north of 42° north latitude. This sample comes from Mukden, Manchuria. Usage same as No. 28057. (*Parker.*)

Grown at Amarillo, Tex., in 1910 and 1911. A description will be found in the classification. A variety of medium height and early maturity, ripening in 92 and 96 days in the two seasons tested.

CLASSIFICATION OF THE KAOLIANGS.

DESCRIPTION OF THE GROUP.

The extensive varietal study which has been conducted with these introductions makes it possible to characterize the group of kaoliangs with some accuracy. From the foregoing descriptions of the various introductions it becomes apparent that there is much diversity of habit, color, etc., among the various varieties. Nevertheless, they have certain characters in common. Among these common characters are dry, pithy, and rather slender stalks, usually only 1 to 3 cm. in butt diameter, bearing relatively few (8 to 11 or sometimes 13) leaves which are comparatively small, 1 to 2.5 feet long and 1 to 2.5 inches wide; glumes never exceeding the seed, almost wholly glabrous, and lemmas always awned.

The rachis and panicle branches are more or less scabrous, but not pubescent except on and around the pulvini or swollen bases of the panicle branches. The sterile spikelets are 3 to 4 mm. long and narrowly lanceolate or elliptical, consisting of the outer glumes. The awn of the lemma is universally present, 2 to 5 mm. long, twisted, and geniculate in the middle.

In habit the kaoliangs vary from 0.7 to 3.6 meters in height, the panicles varying from small, oval, and compact to long, umbelliform, and lax. The glumes vary from gibbous at the base, transversely ridged above the center with depressed and closely appressed apex to thin, flat, and chartaceous; from one-half or two-thirds as long as the seeds to equaling them; from cream or cream buff through various shades of red and brown to black. The seeds also vary in size from 3 to 6 mm. long; in shape from narrowly oval to sublenticular, and in color from chalky white through buff and orange buff to various shades of reddish brown and brown. So far as known all are susceptible to the kernel smut (*Sphacelotheca reiliana*). Almost all lots of seed imported are infected with this disease.

It may be contended that the varieties having glumes gibbous at the base, transversely ridged above the center, and the apices depressed and closely appressed to the seed should really be placed in a group separate from the kaoliangs. These glume characters indicate durra affinities and it is probable that their original Indian progenitors were less widely separated from the durras. In the long time, probably centuries, however, which has elapsed since their introduction to China, they have varied in the same directions as the more typical kaoliangs.

Twenty-seven varieties of kaoliang are described in this paper. Five of these are in the white-seeded section of the group and 22 in the section with brown seeds. Of the 5 varieties having white seeds, 3 fall in the subsection having black glumes and 2 in the subsection with buff glumes. Of the 22 varieties in the brown-seeded section, 8 occur in the black-glumed subsection and 14 in that with buff to red glumes. These 27 varieties include 58 of the 59 separate introductions and accessions described. The remaining one is a recent introduction, which is described but not identified for lack of sufficient data.

KEY TO THE VARIETIES.

I. Seeds white, dirty white, or cream.
  A. Glumes black, shining.
    1. Seeds white, narrowly oval to oval.
      a. Panicles large, lax, oval or subumbelliform, 9 to 14 inches long; plants 8 to 12 feet tall, late.
        Brill Blackhull [Agrost. No. 1442; S. P. I. Nos. 6710 (Agrost. No. 1457), 17920 (G. I. No. 120)].
    2. Seeds dirty white, obovate or sublenticular.
      a. Panicle lax, ovate or ovate conical or one-sided, often nodding, 8 to 12 inches long; plants 6 to 8 feet tall, medium early.
        Korean Blackhull [S. P. I. No. 27553 (G. I. No. 412)].
      b. Panicle semicompact, oval, 7 to 10 inches, erect; plants 5 to 6 feet, medium early.
        Barchet Blackhull [S. P. I. No. 22912 (G. I. No. 310)].

I. Seeds white, dirty white, or cream—Continued.
  B. Glumes buff, often shading to orange buff or orange vermilion.
    1. Seeds white, oval or obovate oval.
      a. Panicle lax, oval or ovate, large, 8 to 12 inches long; plants 6 to 10 feet tall, medium early.
        Mukden White [Agrost. No. 1443; S. P. I. Nos. 18610 (G. I. No. 190), 21077 (G. I. No. 272)].
    2. Seeds cream, obovate to sublenticular.
      a. Panicle lax, elongated, umbelliform, 12 to 15 inches long.
        Headlands Brush [S. P. I. No. 18613].
II. Seeds brown or reddish brown.
  A. Glumes black, shining.
    1. Glumes equaling the seed.
      a. Glumes coriaceous; panicle umbelliform; plants 6 to 8 feet tall, medium late.
        Hoki Brown [Agrost. No. 1585].
      b. Glumes thin, papery; inflorescence paniculate; plants 5 to 6 feet tall, early.
        Paperhull Brown [Agrost. No. 1584; S. P. I. No. 20621 (G. I. No. 263)].
    2. Glumes shorter than the seed.
      a. Seeds medium to large, oval to obovate oval; panicle medium to large, lax, 8 to 14 inches long.
        * Panicle lax, large, 8 to 14 inches long, broadly oval; plants 7 to 10 feet tall, late in maturity.
          Hansen Brown [Agrost. No. 1444; S. P. I. Nos. 225, 3863 (Agrost. No. 1448), 6604 (Agrost. No. 1455 in part), 17921 (G. I. No. 121)].
        ** Panicle lax, large, coarse, 9 to 14 inches long, oval or obovate oval, naked at base; plants 7 to 8.5 feet tall, medium in maturity (105 to 120 days).
          Tientsin Brown [S. P. I. Nos. 17923 (G. I. No. 123), 24991].
        *** Panicle finer, sparse, narrowly oval to cylindrical, 8 to 12 inches long; plant 6 to 8 feet tall, medium-late maturity (115 to 120 days).
          Meyer Brown [S. P. I. Nos. 6411 (Agrost. No. 1454), 18625].
        **** Panicle small to medium, semicompact, oval, 8 to 10 inches long.
          △ Plant 5 to 8 feet tall, medium early, (100 to 110 days).
          Kali Brown [S. P. I. No. 19187 (G. I. No. 193)].
          △△ Plant 4.5 to 7 feet tall, extra early to early (85 to 100 days).
          Manchu Brown [S. P. I. Nos. 939, 18518 (G. I. No. 171), 18611 (G. I. No. 191), 18612 (G. I. No. 192), 20612 (G. I. No. 261), 20620 (G. I. No. 262), 20627 (G. I. No. 264), 24478 (G. I. No. 328), 24992 to 24994 (G. I. No. 171), 24995 (G. I. No. 261)].
      b. Seeds small, broadly obovate or sublenticular.
        * Panicle small, slender, oblong, semicompact, 8 to 11 inches long.
        Hankow Brown [S. P. I. No. 6604 in part (Agrost. No. 1455) (Kans. Exp. Sta. No. 595) (G. I. No. 326)].

- II. Seeds brown or reddish brown—Continued.
  - B. Glumes buff to various shades of red.
    - 1. Glume I flat, glume II keeled, not gibbous or ridged.
      - *a.* Inflorescence umbelliform, rachis shortened.
        - * Panicle medium (9 to 11 inches); branches shorter.
          - **Chihli Brush** [S. P. I. No. 18626].
        - ** Panicle elongated (12 to 18 inches), branches equaling the panicle.
          - **Baird Brush** [S. P. I. Nos. 6406 (Agrost. No. 1453), 18614, 20706 (?) (G. I. No. 265)].
      - *b.* Inflorescence paniculate; oval, ovate or conical.
        - * Panicle broadly oval, lax, heavy, 2.5 to 3.3 dm. (10 to 14 inches) long; rachis somewhat shortened, upper branches 1 to 1.2 dm. (4 to 5 inches) long, more than half as long as the lower; color effect light brown.
          - △ Seeds large, broadly obovate or oval to sublenticular; glumes buff to cardinal and maroon.
            - **Valley Brown** [S. P. I. Nos. 16792 (G. I. No. 152), 21078 (G. I. No. 273), 22911 (G. I. No. 309), 28057 (G. I. No. 423)].
          - △△ Seeds large, oval to obovate; glumes paler.
            - **Moose Brown** [S. P. I. No. 27555 (G. I. No. 414)].
        - ** Panicle conical, lax, heavy, 2.5 to 3.5 dm. (10 to 14 inches) long; upper branches 5 to 7 cm. (2 to 2.8 inches) long; rachis nearly equaling panicle.
          - △ Glumes, especially glume I, exceeding the seed, 5 to 6 mm. long.
            - **Ware Brown** [S. P. I. No. 28027 (G. I. No. 421)].
          - △△ Glumes equaling or, especially glume II, shorter than the seed, 4 to 5 mm. long.
            - + Peduncles red.
              - **Redstem** [S. P. I. No. 22011 (G. I. No. 327)].
            - ++ Peduncles straw color.
              - ○ Lower panicle branches 1.2 to 1.6 dm. (5 to 6.5 inches) long.
                - † Branches stout, rigid; seeds acute.
                  - **Parker Brown** [S. P. I. No. 28058 (G. I. No. 424)].
                - †† Branches slender, flexible; seeds obtuse.
                  - = Seeds elliptical or narrowly oval.
                    - **Shasi Brown** [S. P. I. No. 21678 (G. I. No. 278)].
                  - == Seeds broadly oval to sublenticular.
                    - **Peesan Brown** [S. P. I. Nos. 17922 (G. I. No. 122); 24990].
              - ○○ Lower panicle branches 0.5 to 1 dm. (2 to 4 inches) long.
                - **Ichang Brown** [S. P. I. No. 21676 (G. I. No. 276)].
        - *** Panicle small, oval, compact, 3 to 6 inches long; seeds small, broadly obovate to sublenticular.
          - **Chusan Brown** [S. P. I. Nos. 23230 (G. I. No. 323), 23231 (G. I. No. 324)].

II. Seeds brown or reddish brown—Continued.
  B. Glumes buff to various shades of red—Continued.
    2. Glumes gibbous at the base, transversely ridged above the middle, with depressed apex.
      a. Spikelets small, broadly obovate to sublenticular; panicle large, lax; plants medium height.
        Tokyo Brown: [Agrost. Nos. 1576, 1586; S. P. I. Nos. 4905, 21677 (G. I. No. 277)].
      b. Spikelets medium to large, oval; panicle small to medium, compact.
        *Plant medium; spikelets medium; panicle small, slender.
          Choonchun Brown [S. P. I. No. 27554 (G. I. No. 413)].
        **Plant very dwarf; panicle heavy, compact, oval; spikelets large.
          Shantung Dwarf [S. P. I. No. 22010 (G. I. No. 293)].

DESCRIPTION OF THE VARIETIES.

In the white-seeded section of the kaoliang group five varieties have been distinguished, three in the subsection having black hulls and two in the one having buff hulls. These varieties may be separated and described as follows:

I. *Seeds white, dirty white, or cream.*

A. *Glumes black and shining.*

1. *Seeds white, narrowly oval to oval.*

Brill Blackhull. Agrost. No. 1442; S. P. I. Nos. 6710 (Agrost. No. 1457), 17920 (G. I. No. 120) (Pl. II, *A*). Plants 2.4 to 3.6 meters (8 to 12 feet) tall, bearing 10 to 13 leaves and 1 to 3 suckers each; panicles large, erect, lax, much branched, not always fully exserted, 2.3 to 3.5 dm. (9 to 14 inches) long, and 1 to 1.5 dm. (4 to 6 inches) wide, with rachis one-half to two-thirds as long as the panicle and about equaling the basal branches; spikelets 5 to 7 mm. long; seeds chalky to dirty white, narrowly oval, 4 to 6 mm. long, 3 to 4 mm. wide, covered for three-fourths of their length by the shining black glumes.

A tall, late variety with large open heads, maturing in 120 to 140 days, too tall and late for profitable use. Continued selection for earliness has given but little result so far. It is comparable to Hansen Brown among the brown varieties

2. *Seeds dirty white, obovate or sublenticular.*

a. Panicles large, lax, ovate conical, or one-sided.

Korean Blackhull. S. P. I. No. 27553 (G. I. No. 412) (Pl. II, *B*). Plants 1.8 to 2.4 meters (6 to 8 feet) tall, stoutish, 2.5 to 3 cm. (1 to 1.2 inches) in butt diameter, bearing 10 to 11 leaves; panicle large, lax, ovate conical or one sided, and forming a right-angled triangle, 2.5 to 3.7 dm. (10 to 15 inches) long, often nodding at maturity; lower branches 1.2 to 2.2 dm. (5 to 9 inches) long; spikelets 4 to 4.5 mm. long; seeds 3.5 to 4 mm. long, 3 to 3.5 mm. wide, obovate or sublenticular, dirty white, three-fourths inclosed by the shining black glumes.

A tall medium-early variety with large ovate-conical heads, maturing in 103 and 108 days in the two seasons tested.

b. Panicles medium size, semicompact, oval.

Barchet Blackhull. S. P. I. No. 22912 (G. I. No. 310) (Pl. II, *C*; fig. 14, *e*; fig. 15). Plants 1.3 to 1.6 meters (4.5 to 6 feet) tall, 1.5 to 3 cm. in butt diameter, bearing 8 to 9 leaves; panicle spreading or semicompact, oval or ovate oval, 2 to 2.5 dm. (8 to

10 inches) long, heavy (averaging 3 ounces each), fairly exserted; spikelets 4 to 4.5 mm. long; seeds dirty white, broadly obovate or sublenticular, 3.5 to 4 mm. long, 3 to 3.6 mm. wide, broader in proportion than those of any other white-seeded form; glumes black and shining, covering two-thirds of the seed.

A low, medium-early variety with oval heads, averaging 2 to 2.7 ounces each in different seasons, maturing in 100 days in 1908 and in 105 to 110 in later seasons, classing it as medium early.

B. *Glumes buff, often shading to orange buff or orange vermilion.*

1. *Seeds white, oval or obovate oval.*

a. Panicles lax, oval or semipyramidal, large.

Mukden White. Agrost. No. 1443; S. P. I. Nos. 18610 (G. I. No. 190), 21077 (G. I. No. 272) (Pl. II, *D*; fig. 11; fig. 14, *d*). Plants 1.8 to 3 meters (6 to 10 feet) tall, bearing 9 to 11 leaves and usually no suckers; panicles lax, oval or subconical, large, 2 to 3 dm. (8 to 12 inches) long, with a nearly continuous rachis and the basal branches 1 to 1.5 dm. (4 to 6 inches) long; spikelets 4 to 6 mm. long, broadly oval; seeds 4 to 5 mm. long by 3 to 3.5 mm. wide, oval or obovate oval, white, exserted about one-third of their length; glumes 3 to 4 mm. long, firm, buff to orange buff and orange vermilion.

2. *Seeds cream colored, obovate to sublenticular.*

a. Panicle lax, elongated, umbelliform.

Headlands Brush. S. P. I. No. 18613. Plant not known; original panicle lax, elongated, umbelliform, 3.2 dm. (13 inches) long, probably nodding, the rachis 8 cm. (3 inches) long, bearing 4 whorls of branches; spikelets 4 to 4.5 mm. long, sublenticular, seeds 3.5 to 4 mm. long, 3 to 3.5 mm. wide, broadly obovate to sublenticular, cream colored; slightly exserted; glumes cream colored, shining, covering four-fifths to all of the seed.

Sixteen varieties are found in the section with brown seeds. Seven of these occur in the subsection having black glumes and 14 in the subsection having the glumes varying from buff to different shades of red.

II. *Seeds brown or reddish brown.*

A. *Glumes black, shining.*

1. *Glumes equaling the seeds.*

a. Glumes firm; panicle umbelliform, 12 inches long; plants 6 to 8 feet tall, medium late.

Hoki Brown. Agrost. No. 1585. Plants 1.8 to 2.4 meters (6 to 8 feet) tall; panicle umbelliform, slender, 3 dm. (12 inches) long, becoming reflexed and nodding; branches mostly basal, elongated; rachis, however, extended, its first internode several inches long, bearing terminal whorls of short branches from the second and third nodes; spikelets black, obovate, 4.2 to 5 mm. long; glumes black, shining; seeds obovate oval, 3.7 to 4.3 mm. by 2.8 to 3.5 mm., russet to burnt umber.

A broom-corn type of medium height, heading in 90 days, ripening probably in 120 days, and therefore medium late. Possibly a degenerate form of a true broom corn introduced into Japan from Europe or America.

b. Glumes thin, papery; inflorescence paniculate; plants 5 to 6 feet tall, early.

Paperhull. Agrost. No. 1584; S. P. I. No. 20621 (G. I. No. 263). Plants 1.5 to 2 meters (5 to 6.5 feet) tall, bearing 6 to 8 leaves; panicles sparse, ovate or elliptical, 1.5 to 2.5 dm. (6 to 10 inches) long; spikelets oval, 4.5 to 5.5 mm. long; glumes black, shining, as long as the seeds, thin, chartaceous or papery in texture; seeds oval or narrowly oval, 4 to 5 mm. by 2.5 to 3 mm., russet to burnt umber.

A rather low variety, extra early to early, maturing in 85 to 95 or 100 days. The name was suggested by the character of the glumes.

2. *Glumes shorter than the seed.*

a. Seeds medium to large, oval to obovate oval; panicle medium to large, lax, 7 to 14 inches long.

* *Panicle lax, large, 8 to 14 inches long, broadly oval; plants 7 to 10 feet tall, late in maturity.*

Hansen Brown. Agrost. No. 1444; S. P. I. Nos. 225, 3863, 6604 (in part), 17921 (G. I. No. 121) (Pl. II, *E;* fig. 8, *a*, *b*; fig. 9). Plants tall, stoutish, 2 to 3 meters (7 to 10 feet) high, bearing 9 to 13 leaves and 1 to 3 suckers; panicles lax, broadly oval, 2 to 3.5 dm. (8 to 14 inches) long, 1 to 2 dm. (4 to 8 inches) wide, heavy; spikelets 4 to 5.5 or 6 mm. long; seeds obovate oval, 3.5 to 5.5 mm. long by 3 to 4.5 mm. wide, bay, walnut brown, or cinnamon, bleaching to burnt sienna and buff; glumes shining black, about one-third shorter than the seeds.

A tall, late variety, maturing in 120 to 140 days. Named for Prof. N. E. Hansen, horticulturist of the South Dakota Experiment Station and Agricultural College and agricultural explorer for the United States Department of Agriculture, who sent the seed of S. P. I. No. 225, the earliest official introduction. Comparable to Brill Blackhull among the white-seeded varieties.

** *Panicle lax, large, coarse, 9 to 14 inches long, oval or obovate oval, naked at base; plants 7 to 8.5 feet tall, medium in maturity (105 to 120 days).*

Tientsin Brown. S. P. I. Nos. 17923 (G. I. No. 123), 24991 (Pl. II, *F;* fig. 9). Plants 2 to 2.5 meters (7 to 8.5 feet) tall, stoutish, bearing 10 to 12 leaves; panicles large, lax, much branched, oval, 2.2 to 3.5 dm. (9 to 14 inches) long; basal branches 1 to 1.7 dm. (4 to 7 inches) long, ascending to appressed, commonly naked for half their length; spikelets large, oval, 4 to 6 mm. long; glumes black, or occasionally claret, shining; seeds large, mostly oval, some obovate, 4 to 5.5 mm. long by 3.4 mm. wide, one-third exserted, clay to russet and bay.

A variety of medium height and maturity, ripening in 105 to 120 days. The large heads are not well filled at the base. Differs from Hansen Brown chiefly in being earlier.

*** *Panicle finer, sparse, narrowly oval to cylindrical, 8 to 12 inches long; plant 6 to 8 feet tall, medium-late maturity (115 to 120 days).*

Meyer Brown. S. P. I. Nos. 6411 (Agrost. No. 1454), 18625 (fig. 8, *d*). Plants 1.8 to 2.4 meters (6 to 8 feet) in height; panicles lax, medium to large, 2 to 3 dm. (8 to 12 inches) long, oval or narrowly oval; lower branches 7 to 12 cm. (2.5 to 5 inches) long; rachis two-thirds as long as to equaling the panicle; spikelets oval, 4.5 to 6 mm. long; glumes shining, mostly black, occasionally seal brown; seeds 3.5 to 5.5 mm. long, 3 to 4 mm. wide, oval or obovate, exserted one-fourth, russet to bay or chocolate. A variety of medium height and medium maturity, ripening in 115 to 120 days.

**** *Panicle small to medium, oval, semicompact, 8 to 10 inches long.*

△ *Plant 5 to 8 feet tall, medium early (100 to 110 days).*

Kali Brown. S. P. I. No. 19187 (G. I. No. 193) (Pl. II, *G*). Plants slender, 1.5 to 2.4 meters (5 to 8 feet) in height; panicles small, rather compact, 1.5 to 2.2 dm. (6 to 8 inches) in length, the lower branches 5 to 10 cm. (2 to 4 inches) long, and the rachis five-eighths to five-sixths as long as the panicle; spikelets 4.5 to 5.5 mm. long; glumes

3 to 4 mm. long, black, shining; seeds obovate oval, 4 to 5 mm. long by 3 to 4 mm. wide; walnut brown or burnt umber or paler. A low to medium variety, early to medium early in maturity, ripening in 100 to 110 days. Differs from Manchu Brown chiefly in greater height and later maturity. Name suggested by its reported use on alkali soils.

△△ *Plant 4.5 to 7 feet tall, extra early to early (85 to 100 days).*

Manchu Brown. S. P. I. Nos. 939, 18518 (G. I. No. 171), 18611 (G. I. No. 191), 18612 (G. I. No. 192), 20612 (G. I. No. 261), 20620 (G. I. No. 262), 20627 (G. I. No. 264), 24478 (G. I. No. 328), 24992-24994 (G. I. No. 171), 24995 (G. I. No. 261) (Pl. II, *H;* fig. 10; fig. 12).

Plants 1.4 to 2 meters (4.5 to 7 feet) in height, slender, bearing 7 to 9 leaves and usually no suckers or only one per plant; panicles oval or narrowly ovate, 2 to 2.7 dm. (8 to 10 or 11 inches) long; spikelets oval, acute, 4.5 to 5.5 or 6 mm. long; glumes black, shining, exposing one-third of the seed; seeds obovate oval to oval, 4 to 5.5 mm. long, 3 to 4 mm. wide, mostly dark brown, as burnt sienna, burnt umber, and chocolate where exposed, and buff to russet where included.

A low to medium variety of Manchurian origin, extra-early to early, maturing in 85 to 105 or 110 days, according to locality and season. The most important variety, agronomically, extending the use of these plants into the Northern States.

b. *Seeds small, broadly obovate or sublenticular.*

* *Panicle small, slender, semicompact, 8 to 11 inches long.*

Hankow Brown. S. P. I. No. 6604 in part (Kans. Exp. Sta. No. 595) (G. I. No. 326) (Pl. II, *I*). Plants 1.5 to 2.1 meters (5 to 7 feet) in height; stems stoutish, 2.5 to 3 cm. (1 to 1.2 inches) in butt diameter; leaves 9 to 12 in number; panicles slender, oblong, semicompact, 2 to 3 dm. (8 to 12 inches) long; lower branches 6 to 10 cm. (2.5 to 4 inches) long; butts poor to fair; rachis continuous; spikelets 4 to 5 mm. long; seeds 3 to 4 mm. long by 2.5 to 3 mm. wide, obovate or broadly obovate to sublenticular, walnut brown to chocolate, scarcely exserted; glumes black, shining.

A medium-low variety, medium early in maturity, ripening in 105 to 112 days.

B. *Glumes buff to various shades of red.*

1. *Glume I flat, glume II keeled, not gibbous or ridged.*

a. *Inflorescence umbelliform, rachis shortened.*

* *Panicle medium (9 to 11 inches); branches shorter.*

Chihli Brush. S. P. I. No. 18626. Plants 1.8 to 2.4 meters (6 to 8 feet) in height; panicles obovate or obconical, umbelliform, heavy, much branched, 2.2 to 2.7 dm. (9 to 11 inches) long; branches 1 to 1.7 dm. (4 to 7 inches) long; rachis about one-third as long as the panicle; spikelets 4.5 to 5.5 mm. long, obovate oval; glumes cinnamon red to brick red to black; seeds obovate, 4 to 5 mm. long by 3 to 4 mm. wide, cream buff to burnt sienna, exserted one-fourth to one-third. Time of maturing not recorded.

** *Panicle elongated (12 to 18 inches); branches equaling the panicle.*

Baird Brush. S. P. I. Nos. 6406, 18614, 20706 (?) (G. I. No. 265) (fig. 9, *c*). Plants 1.8 to 2.7 meters (6 to 9 feet) in height; panicles very lax, 3 to 4.5 dm. (12 to 18 inches) long, umbelliform or with the rachis more or less produced, branches equaling the panicle, spreading and drooping, or appressed and the whole panicle nodding; spikelets oval, 4.5 to 6 mm. long; glumes shining, clay to tawny, 4 to 5 mm. long, covering three-fourths or more of the seed; seeds obovate to oval, clay to russet, one-fourth exserted, 4 to 5.5 mm. long by 3 to 3.5 mm. wide.

A medium to tall variety, medium late (120 days) in maturity, of value only as a possible stock for broom-corn experiments.

b. Inflorescence paniculate; oval, ovate, or conical.

* *Panicle broadly oval, lax, heavy, 2.5 to 3.5 dm. (10 to 14 inches) long; rachis somewhat shortened, upper branches 1 to 1.2 dm. (4 to 5 inches) long, more than half as long as the lower; color effect, light brown.*

△ *Seeds large, broadly obovate or oval to sublenticular; glumes buff to cardinal and maroon.*

Valley Brown. S. P. I. Nos. 16792 (G. I. No. 152), 21078 (G. I. No. 273), 22911 (G. I. No. 309), 28057 (G. I. No. 423) (Pl. II, *J;* fig. 14, *a*, *c*). Plants 1.8 to 2.7 meters (6 to 9 feet) in height, stoutish, bearing 8 to 11 leaves, 7 to 9 cm. (2.7 to 3.5 inches) wide, and 6 to 6.7 dm. (2 to 2.2 feet) long; panicles large, broadly ovate or oval, heavy, 2.5 to 5 dm. (10 to 15 inches) long and half as wide, the lower branches 1 to 2 dm. (4 to 8 inches) long, the upper 1 to 1.2 dm. (4 to 5 inches) long; spikelets obovate, 4.2 to 5.7 mm. long; glumes mostly buff to clay, shading to cardinal, burnt sienna, and even maroon, seeds large, broadly obovate oval to sublenticular or subspherical, less flattened than most varieties, 3.5 to 5 mm. long by 2.5 to 4 mm. wide, cream, or mostly buff or clay, to russet, chestnut, and burnt umber.

A variety of medium height and early to medium-early maturity, ripening in 95 to 105 days. G. I. No. 309, especially, is considered very promising as a variety for middle latitudes and elevations.

△△ *Seeds large, oval to obovate; glumes paler.*

Moose Brown. S. P. I. No. 27555 (G. I. No. 414). Plants 2 to 2.4 meters (6.5 to 8 feet) in height, stoutish, 1.3 to 2.5 cm. (0.5 to 1 inch) in butt diameter; leaves 11 to 13 in number, 6 to 7.5 cm. (2.2 to 3 inches) wide, 7 to 7.5 dm. (2.2 to 2.5 feet) long; panicles large, lax, subconical or mostly one-sided and forming a right-angled triangle in shape, 2.5 to 3.5 dm. (10 to 14 inches) long, lower branches 7 to 15 cm. (3 to 6 inches) long, upper branches 1 dm. (4 inches) long; rachis about three-fourths as long as the panicle; spikelets 4.5 to 5 mm. long; glumes coriaceous, 4.5 to 5 mm. long, clay to burnt sienna or, in 1910 and 1911, a shining cream, edged with pink to hazel; seeds oval or obovate, 4 to 4.7 mm. long by 3 to 3.5 mm. wide, in original sample clay to chestnut, nearly included, much paler in 1910 and 1911. A variety of medium height and of medium-late maturity, ripening in 114 and 120 days in the two seasons tested.

** *Panicle conical, lax, heavy, 2.5 to 3.5 dm. (10 to 14 inches) long; upper branches 5 to 7 cm. (2 to 2.8 inches) long; rachis nearly equaling the panicle.*

△ *Glumes, especially glume I, exceeding the seed, 5 to 6 mm. long.*

Ware Brown. S. P. I. No. 28027 (G. I. No. 421) (Pl. II, *K*). Plants 1.6 to 2 meters (5.5 to 6.5 feet) in height, slender to medium; leaves 10 to 11 in number, 7 to 8 cm. (2.7 to 3.2 inches) wide, 6 to 6.7 dm. (2 to 2.2 feet) long; panicles conical, lax, heavy (elliptic-oval in part of original plants), 2.5 to 3.5 dm. (10 to 14 inches) long, lower branches 1.2 to 1.7 dm. (5 to 7 inches) in length, upper branches 5 to 7 cm. (2 to 2.8 inches) long; rachis nearly equaling panicle; spikelets 4.5 to 5 mm. long; glumes raw sienna to Chinese orange and maroon or, in 1911, cream buff to cinnamon rufous, tinged with heliotrope; seeds obovate or oval, 4 to 4.5 mm. long by 3 to 3.8 mm. wide, clay to russet to burnt sienna, in 1910 clay tipped with hazel to brick red. A medium-low and early to medium-early variety, ripening in 92 days in 1910 and in 92 to 110 days in 1911.

△△ *Glumes equaling or shorter, especially glume II, than the seed, 4 to 5 mm. long.*

+ *Peduncles red.*

Redstem. S. P. I. No. 22011 (G. I. No. 327). Plants medium, 1.8 to 2.7 meters (6 to 9 feet) in height; slender to medium in diameter and usually without suckers; culms, especially the upper internodes, peduncle and rachis a beautiful madder brown or maroon; leaves 9 to 12 in number, 5 to 7 cm. (2 to 2.7 inches) wide, 6 to 6.7 dm. (2 to 2.2 feet) long; panicles sparse, light weight, lax, ovate or becoming one-sided by the bending of the peduncle, 2.2 to 3 dm. (9 to 12 inches) long, the lower branches 7 to 15 cm. (3 to 6 inches) long, spreading; rachis nearly equaling the panicle; spikelets large, oval, or suboval, 4.5 to 6 mm. long; glumes orange vermilion to maroon, occasionally buff; seeds oval or obovate oval, 4 to 5 mm. long by 3 to 3.7 mm. wide, cream buff to hazel to bay, one-fifth exserted. An early variety of medium height, ripening in 95 days, and strikingly characterized by the reddish brown stems. Of little value because of the light, sparse panicle.

++ *Peduncles straw color.*

○ *Lower panicle branches 1.2 to 1.6 dm. (5 to 6.5 inches) long.*

† *Branches stout, rigid; seeds acute.*

Parker Brown. S. P. I. No. 28058 (G. I. No. 424) (Pl. II, *L*). Plants 1.8 to 2.1 meters (6 to 7 feet) in height, 1.2 to 2 cm. (0.5 to 0.8 inch) in diameter at the butt; leaves 10 to 12 in number, 9 to 10 cm. (3.5 to 4 inches) wide, 6 to 6.7 dm. (2 to 2.2 feet) long; panicles exserted 7 to 15 cm. (3 to 6 inches), narrowly elliptical, 2.2 to 3 dm. (9 to 12 inches) long; branches stout, rigid, the lower 1 to 1.5 dm. (4 to 6 inches) in length; rachis three-fifths as long as the panicle; spikelets 4 to 5 mm. long; glumes vinaceous cinnamon to maroon to black in 1910, and clay to hazel to chestnut in 1911; seeds rhombic oval to obovate, acute, 3.5 to 5 mm. long by 3 to 4 mm. wide, buff to burnt sienna in the original and in 1911, in 1910 cream to raw sienna to hazel. A variety of medium height and early maturity, ripening in 92 and 96 days in the two seasons tested.

†† *Branches slender, flexible; seeds obtuse.*

= *Seeds elliptical or narrowly oval.*

Shasi Brown. S. P. I. No. 21678 (G. I. No. 278) (Pl. II, *M*). Plants 1.9 to 2.4 meters (6.5 to 8 feet) in height, culms 2 to 2.5 cm. (0.7 to 1 inch) in butt diameter; leaves 10 to 11 in number, 5 to 6.5 cm. (2 to 2.5 inches) wide by 6.7 to 7.5 dm. (2.2 to 2.5 feet) long; panicles broadly conic, or one-sided from the leaning of the culms, 2.7 to 3.5 dm. (11 to 14 inches) long, exserted 2.5 to 7.5 cm. (1 to 3 inches), branches slender, flexible, the lower 1 to 2 dm. (4 to 8 inches) long, the upper 6 to 7 cm. (2.5 to 3 inches) long; spikelets 4 to 5.3 mm. long; glumes 3.5 to 4 mm. long, clay and tawny to orange vermilion, ferruginous and crimson; seeds oval, broadly oval or obovate, 3.8 to 4.7 mm. long by 2.8 to 3.6 mm. wide, mostly russet or some burnt umber in original sample, cream buff to burnt sienna in 1911, about one-third exserted. A variety of medium stature and maturity, ripening in 110 days in the single test made.

= = *Seeds broadly oval to sublenticular.*

Peesan Brown. S. P. I. Nos. 17922 (G. I. No. 122), 24990 (Pl. II, *N*). Plants 1.8 to 2.4 meters (6 to 8 feet) in height, bearing 9 to 11 leaves, 9 to 11 cm. (3.5 to 4.5 inches) wide, 6 to 6.7 dm. (2 to 2.2 feet) long; suckers 1 to 3 in number; panicles conical, 1.5 to 2.7 dm. (6 to 11 inches) long, mostly one-sided by the flexing of the peduncle; branches slender, the lower 1 to 1.5 dm. (4 to 6 inches) long; spikelets oval, 4 to 5.6 mm.

long: glumes covering three-fourths of the seed, clay to madder brown; seeds mostly oval, some broadly obovate, 3.5 to 5 mm. long by 3 to 4 mm. wide, russet to bay in original, some of the later generations cream buff to raw sienna to hazel.

The original was a considerable mixture from which has been isolated the low and medium-early strain, G. I. No. 122, 4.5 to 5.5 feet in height and maturing in 110 to 115 days.

○○ *Lower panicle branches 5 to 10 cm. (2 to 4 inches) long.*

Ichang Brown. S. P. I. No. 21676 (G. I. No. 276). Plants about 2 meters (7 feet) high, culms stout, 2.5 to 3 cm. (1 to 1.2 inches) in butt diameter; leaves 11 to 13 in number, 7 to 9 cm. (3 to 3.7 inches) in width, 7.5 to 8 dm. (2.5 to 2.7 feet) long; panicles conical, loose, 2.7 to 3.2 dm. (11 to 13 inches) long, exserted 2 to 7.5 cm. (1 to 3 inches), lower branches 0.5 to 1 dm. (2 to 4 inches) long, upper branches 3 to 5 cm. (1 to 2 inches) long; spikelets obovate oval, 4 to 4.8 mm. long; glumes clay and cardinal to madder brown and claret brown; seeds broadly oval to obovate oval, 3.5 to 4.5 mm. long by 2.8 to 3.8 mm. wide, cream to chestnut to burnt sienna. A variety of medium height and medium maturity, ripening in 110 days in the single test made. Distinguished from Peesan Brown chiefly by the longer heads and darker glumes. Quite probably it is equivalent to one of the forms discarded from S. P. I. No. 17922, from which Peesan Brown was selected.

*** *Panicles small, oval, compact, 3 to 6 inches long; seeds small, broadly obovate to sublenticular.*

Chusan Brown. S. P. I. Nos. 23230 (G. I. No. 323), 23231 (G. I. No. 324) (Pl. II, *O*). Plants low to medium, 1.2 to 2 meters (4 to 7 feet) in height, bearing 8 to 10 leaves, 8 to 10 cm. (3.2 to 4 inches) wide, 6.7 to 7.5 dm. (2.2 to 2.5 feet) in length; panicles small, 1.2 to 2 dm. (5 to 8 inches) long, narrowly oval, lower branches 2 to 3.5 inches long, seeded to their base, rachis equaling the panicle; spikelets broadly obovate, 3.5 to 4.2 mm. long; glumes short, brick red to maroon or chestnut to bay, shining; seeds small, broadly obovate or sublenticular, 3 to 4 mm. long by 2.5 to 3.5 mm. wide, bay to burnt umber to chocolate. A low to medium variety with small, compact panicles and small, nearly round seeds; medium to medium late, ripening in 110 to 129 days. Of little promise.

2. *Glumes gibbous at the base, transversely ridged above the middle, with depressed tip.*

a. *Spikelets small, broadly obovate or sublenticular; panicle large, lax; plant medium height.*

Tokyo Brown. Agrost. Nos. 1576, 1586; S. P. I. Nos. 4905 (G. I. No. 277), 21677 (Pl. II, *P*). Plants 1.5 to 2.1 meters (5 to 7 feet), slender to medium, suckering freely; leaves 11 to 12 in number, 8 to 10 cm. (3.5 to 4 inches) wide, 7.5 to 8.2 dm. (2.5 to 2.7 feet) in length; panicles lax, ovate-conical, large, 2 to 3.5 dm. (8 to 14 inches) long, heavy, apex often nodding, branches 1 to 1.5 dm. (4 to 6 inches) long, ascending or spreading and nodding at the apex; spikelets mostly 3 to 4 mm. long, almost spherical; glumes coriaceous, short, transversely shouldered or ridged, the apex depressed and closely appressed to the seed, clay to brick red or vinaceous cinnamon to maroon in the first two and last forms, from mostly cream buff through heliotrope to burnt sienna and claret brown in the third; seeds 3 to 4 mm. by 2.5 to 3.8 mm. in size and mostly chestnut to burnt sienna or darker, very broadly obovate to nearly lenticular in the first two and last, still smaller, rounder, and clay or dark clay in the third. A low to medium variety of medium maturity, ripening in about 110 days.

b. Spikelets medium to large, oval; panicle small to medium, compact.

**Plant medium; spikelets medium; panicle small, slender.*

Choonchun. S. P. I. No. 27554 (G. I. No. 413) (Pl. II, *Q*). Plants slender, 1.3 to 2 meters (4.5 to 6.5 feet) tall, medium stout, bearing 10 to 12 leaves, 7.5 to 9 cm. (3 to 3.5 inches) wide, 6 to 6.7 dm. (2 to 2.2 feet) long; panicle small, cylindric oval, compact, 1.5 to 2 dm. (6 to 8 inches) long, with continuous rachis, lower branches 7.5 to 10 cm. (3 to 4 inches) long; spikelets ovate or broadly oval, 4.5 to 5 mm. long; glumes 3 to 3.5 mm. long, clay to orange vermilion to deep crimson, edged with dark brown, covering two-thirds of the seed; seeds broadly oval or obovate oval, 4 to 5 mm. long by 3 to 3.8 mm. wide, clay to russet to burnt umber, or cream buff to brick red in 1910. A low variety of medium-early maturity, ripening in 103 and 98 days in the two seasons grown. Not promising.

***Plant very dwarf; panicle heavy, compact, oval; spikelets large.*

Shantung Dwarf. S. P. I. No. 22010 (G. I. No. 293) (Pl. II, *R;* fig. 13; fig. 14*b*). Plants stout, very dwarf, 0.6 to 0.9 meter (2 to 3 feet) tall, averaging 2.5 cm. (1 inch) in diameter at the butt; leaves 8 to 11 in number, 1 to 1.2 dm. (4 to 4.8 inches) wide, 5.2 to 6 dm. (1.7 to 2 feet) in length; panicles stout, heavy (averaging 3 ounces each) oval, compact, 2 to 2.5 dm. (8 to 10 inches) long; spikelets broadly oval, occasionally obovate or even ovate, 4 to 5.5 mm. long; glumes 3.5 to 4 mm. long, gibbous at the base, transversely ridged above the center, the apex depressed and closely appressed to the seed, buff to burnt sienna or in later years cream to clay and madder brown; seeds broadly oval or obovate, 4 to 5 mm. long by 3 to 4 mm. wide, one-third exserted, russet to burnt umber, or, in later years, raw sienna to burnt sienna. A very dwarf, medium-early variety, 2 to 3 feet in height, and maturing in 100 to 110 days.

AGRICULTURAL VALUE.

GENERAL CHARACTERS.

The kaoliangs have been too recently introduced and have required too much rigid selection to allow final judgment as to their place among the grain varieties. They are of almost no value as forage, owing to the dry stems and the few and small leaves. They are not likely to displace any of the leading groups of grain sorghums, such as the milos, durras, and kafirs, now grown in this country. At the same time, on account of their earliness, and perhaps greater hardiness also, they have apparently a distinct place of their own to fill in the more northern and more elevated parts of the dry-farmed areas.

As previously stated, the kaoliang varieties, when introduced from the Orient, are frequently mixtures of varieties and almost certainly mixtures of races or strains also. In order to obtain uniformity and value as grain producers it has been necessary to isolate the highest producing strains by the head-to-row method. Table V shows the number of varieties or separate introductions under test since 1906 and also the number of selections made each year and the number of these selections which were planted the succeeding season.

TABLE V.—*Record of kaoliang varieties or introductions under test at the experiment farm of the Office of Grain Investigations at Amarillo, Tex., since 1906, and the number of selections made therefrom annually.*

Year.	Planted.				Selections made.		
	Number of lots—			Number of select heads.	Number of lots—		Number of heads selected.
	From original seed.	From select heads.	Total.		Dis-carded.	Selected.	
1906	6	0	6	0	1	5	43
1907	11	5	16	43	3	13	391
1908	6	11	17	243	2	15	479
1909	5	11	16	150	1	15	610
1910	7	15	22	164	0	22	440
1911	3	22	25	186	0	25	255

The group contains a large assortment of varieties, some early, some late; some dwarf, some tall; some compact, some lax in panicle; some with large seeds and some with small. They all unite in having small to medium stalks, containing dry pith and bearing comparatively few (6 to 11) leaves. Since the crop has so little forage value the tall varieties are not desirable. The late varieties are usually tall also, but even if they were not they would have no advantage, except possible lower water requirements, over the equally late kafirs in regions where late sorts can be matured. The medium-maturing varieties of medium or low stature must compete with the well-known and popular milo varieties as grain producers and are of even less value for forage. Their chief advantage is their always erect head. It follows, then, that there is real need at present for only the very early strains which can be matured farther north and at higher elevations than milos. Such varieties have been obtained, improved by some years of selection, and are now giving good results in South Dakota and other points farther north, as well as on the elevated plains of New Mexico and Colorado.

Owing to their low water requirements and tendency to produce but one stalk from a seed it has been possible to mature good crops of kaoliangs in dry years where milo largely failed. If moisture is comparatively abundant in the early part of the growing period, milo is likely to put forth so many suckers as to seriously handicap the crop when dry weather sets in. The kaoliangs are less prolific in this regard and can therefore endure drought more successfully. This fact gives value to the kaoliangs in the drier parts of the central Plains area. The kaoliangs seem also to be slightly less susceptible to chinch-bug injury than the milos, though more so than the kafirs.

PROMISING VARIETIES.

Out of the considerable number of actual varieties tested and classified, only a few give promise of definite value for definite areas.

All of these are early or medium in maturity. The later varieties are not only tall, which is objectionable, but can scarcely compete with the popular milo and kafir varieties.

From the standpoint of the characters and quality of the seed there is probably but little to choose among the varieties. The members of the white-seeded section are perhaps preferable because the seed coats contain no tannin. But because of this very fact they are the more eagerly sought by birds. Small fields are often severely damaged by the inroads of English sparrows, blackbirds, and other species. To date it is true also that the earliest forms in the white-seeded section are appreciably later than the earliest of the brown-seeded sorts. However, earlier white strains are being evolved and the present superiority of the brown varieties in this respect is likely to be diminished gradually.

As to other characters than color of the seed there is little choice among the different varieties except in earliness. For use at high elevations and in northerly latitudes the very earliest strains must be chosen. Under more favorable conditions any of the best producing varieties may be safely used.

Tests in the Texas Panhandle.—Table VI shows the performance of some of the best sorts at the Amarillo experiment farm of the Office of Grain Investigations during the past four years. Some of these varieties were under experiment at that point previous to 1908, but pure strains were not available for plat tests before that year. In 1908 most of the tests were in hundredth-acre or fiftieth-acre plats. In 1909, 1910, and 1911 all the standard sorts were tested in one or more tenth-acre plats. The yields recorded for 1910 and 1911 are often the average of several tenth-acre plats, in one case as many as seven being averaged.

TABLE VI.—*Length of growing period, height, and yield per acre of several varieties of kaoliang at the experiment farm, Amarillo, Tex.*

G. I. No.	Variety.	Growing period.	Height.	Yields per acre.				
				1908	1909	1910	1911	Average.
		Days.	*Feet.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
120	Brill Blackhull	120–135	7–12			1.84	19.31	10.57
412	Korean Blackhull	100–105	6–8			*10.34	15.96	13.15
310	Barchet Blackhull	100–110	4.5–5.5	*43.10	†9.44	8.58	†30.75	22.97
190	Mukden White	105–115	5–8		12.80	12.19	25.07	16.68
272	do	100–115	6–8	*18.10	15.74	*7.24	21.18	15.56
123	Tientsin Brown	105–120	7–8	*31.31	9.89	6.52	27.50	18.80
193	Kali Brown	100–110	5–8	*26.29	12.82	9.95	25.05	18.53
171	Manchu Brown	90–100	4.5–6	†33.38	†14.19	†14.32	29.29	22.77
261	do	85–95	4.5–6.5	20.85	11.43	6.16	†16.99	13.86
328	do	85–95	4.5–6			7.45	†21.36	14.40
309	Valley Brown	95–105	6	*37.41	16.03	†15.01	30.98	24.86
122	Peesan Brown	110–115	5–6	†33.86	†14.76	11.69	26.85	21.79
324	Chusan Brown	110–120	4–6			* 6.47	21.30	13.89
293	Shantung Dwarf	105–110	2.5–3	*33.62	3.49	6.64	27.62	17.84

* Less than a twentieth-acre plat. † Average of two or more tenth-acre plats.

The yields for the first three years are in decreasing series, due to severe climatic conditions. The rainfall for the past five years at the Amarillo farm is shown in the following table:

TABLE VII.—*Precipitation in inches per month at Amarillo, Tex., for five years from 1907 to 1911.*

Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1907	1.11	0.24	0.02	1.25	0.99	1.97	1.49	6.20	0.91	1.79	0.66	1.46	18.09
1908	.26	.72	T.	1.90	3.55	1.73	5.40	2.75	1.83	.40	.51	.00	19.05
1909	.07	.28	1.28	.50	1.08	4.72	3.63	.87	2.19	1.18	3.25	.54	19.59
1910	.05	.17	.34	.53	2.61	1.15	2.94	2.44	.05	.13	.19	T.	10.60
1911	.13	2.88	.50	2.76	5.88	.20	3.85	2.97	.83	.84	.94	.95	22.73

The rainfall of four of these five years was below the average for the 15 years preceding 1907, which was 22.5 inches. The yields recorded for 1908 are good, those for 1909 average less than half as large, while those of 1910 are still lower. In 1911 the yields rise again. The discrepancy in the yields of 1908 and 1909 does not arise from a difference in annual precipitation, but from the difference in seasonal distribution and in part from the cumulative effect. In 1908 the rainfall was abundant during the six months, April to September, which determine the success of these summer crops, being highest in May, the month of planting, and in July, the month of greatest growth. In 1909, on the other hand, the season was dry until June, and August, the month of heading or ripening, was also very dry. The yields of the year 1910 are readily explained by the very deficient rainfall following a fairly dry season in 1909. The average yields for the four years are very good, considering the seasonal conditions. That four of these kaoliang varieties should have been able to produce average yields of more than 20 bushels an acre under the conditions obtaining in these four years is very gratifying. Five other varieties or strains made average yields ranging from 13.8 bushels to 18.8 bushels in the same period. The average yield for these nine strains is 19.7 bushels for the four-year period.

In comparison with the above records, nine varieties of corn made an average yield in 1908 of only 10.06 bushels per acre. In 1909 a larger number of varieties ranged from nothing to about 7 bushels in yield, while in 1910 no yields whatever were obtained. In 1911 the average yield of 26 varieties was 4.27 bushels per acre. The best variety of corn, a red dent of local origin, averaged only 10.02 bushels for this four-year period. The three-year average of all corn varieties was certainly much below 5 bushels.

Tests in the central Plains area.—The performance of these kaoliangs at Amarillo may be taken as a fair sample of what may be expected of them in the grain-sorghum belt or the southern half of the Great Plains area, due allowance being made for differences in elevation, rainfall, etc. Similar results have been obtained at the experiment farm, Dalhart, Tex., in cooperation with the Office of Dry-Land Agriculture. Tests by large numbers of cooperating farmers in Oklahoma, Kansas, New Mexico, and Colorado have given results as good as or better than those cited above.

The choice of varieties from among the best recorded in Table VI will be governed largely by the need for earliness. For Texas, Oklahoma, and western Kansas such varieties as Barchet Blackhull and Manchu Brown, Kali Brown, Valley Brown, and Peesan Brown are well adapted. For the higher elevations in New Mexico and Colorado as well as for western Nebraska and South Dakota only the earliest strains of Manchu Brown are certain to mature.

Manchu Brown, as noted in the discussion of introductions, is a very early variety of low stature originating in Manchuria. It was obtained from several widely separated localities of that division and is probably the dominant, if not, indeed, the only variety grown in the higher latitudes of Manchuria and the adjacent provinces of Siberia. It is possible that its northern origin has given it the power of germinating at lower mean daily temperatures than varieties originating farther south. At any rate, better stands are usually obtained from strains of this variety in the Dakotas and Montana than from any other kaoliangs or any other group of grain sorghums.

Tests in South Dakota.—Three strains of Manchu Brown have been successfully grown in South Dakota. These are G. I. Nos. 171, 261, and 328. The exact origin of the first two is not known, but the last comes from the Harbin district, in the province of Kirin, at 46° north latitude, or higher. The tests were made at the Highmore substation in cooperation with the department of agronomy of the South Dakota Agricultural Experiment Station, and the earlier results have already been published by Willis and Champlin,[1] of that station.

The latitude of Highmore is 44.5° north, the elevation 1,890 feet, the average annual rainfall 17.4 inches, and the soil a glacial clay loam.

Table VIII contains the data obtained in these tests during 1909 and 1910, adapted from the table on page 54 of the bulletin cited, with the data for 1911 added. The average yield of the three strains for the two years is seen to be 16.5 bushels, and for the three years 13.7 bushels per acre. These kaoliangs were tested each year in tenth-acre plats, drilled in rows 3.5 feet apart with a row space of about 6 inches for each plant.

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[1] Willis, Clifford, and Champlin, Manley. Progress of Grain Investigations. Bulletin 124, South Dakota Agricultural Experiment Station, November, 1910, p. 54.

The year 1910 was deficient in rainfall at Highmore, and 1911 will long be remembered for the drought prevailing during the growing season of these crops.

TABLE VIII.—*Results with Brown Manchu and Barchet Blackhull kaoliangs at Highmore (S. Dak.) substation, 1909 to 1911.*

Year.	Data of test.	Varieties.				
		Manchu Brown.				Barchet Blackhull, G. I. No. 310.
		G. I. No. 171-8, Highmore No. 92.	G. I. No. 261-4, Highmore No. 91.	G. I. No. 328, Highmore No. 90.	Average yield of three strains.	
1909	Planted	May 19	May 19	May 19		May 19
	Headed	Aug. 7	Aug. 4	Aug. 1		Aug. 14
	Ripened	Sept. 12	Sept. 10	Sept. 10		Oct. 12
	Days to mature	117	114	114		146
	Yield...bushels	14.8	14.0	14.8	14.5	2.4
1910	Planted	May 18	May 18	May 18		
	Headed	July 30	Aug. 2	Aug. 2		
	Ripened	Sept. 12	Sept. 9	Sept. 7		
	Days to mature	116	114	110		
	Yield...bushels	19.2	20.0	16.4	18.5	
	Average yield for 2 years...do	17.0	17.0	15.6	16.5	
1911	Planted	May 19	May 19	May 19		
	Headed	Aug. 4	July 31	Aug. 1		
	Ripened	Sept. 5	Sept. 1	Sept. 1		
	Days to mature	109	105	105		
	Yield...bushels	10.3	6.0	8.2	8.2	
	Average yield for 3 years...do	14.8	13.3	13.1	13.7	

Fifteen varieties of corn grown in 1909 gave an average yield of 18.2 bushels per acre. The varietal test, continued for three years, was then abandoned and only the two best varieties were grown in 1910. Eighteen plats of Minnesota No. 13 averaged 7.5 bushels, and fourteen plats of Brown County Yellow averaged 9.7 bushels per acre. In 1911 a single ear-row plat of each was grown, yielding 15.3 and 6.8 bushels per acre, respectively.

At the Bellefourche experiment farm, Newell, S. Dak., experiments are conducted in cooperation with the Office of Western Irrigation Agriculture. The latitude is 44.7° north, the elevation 2,900 feet, the average annual precipitation 14 or 15 inches, and the soil a heavy clay or gumbo. The effects of the increased altitude and latitude, heavier soil, and lower precipitation are indicated by the results given in Table IX. The tests were conducted by Mr. Cecil Salmon, in charge of grain investigations at that station.

In 1909 the strains were tested in hundredth-acre head rows, except No. 171, which was in a tenth-acre plat. In 1910 all strains were tested in two-hundredth-acre head rows. While the yields so far obtained are not high, they give promise that further selection will result in profitable strains. The spring and summer of 1911 were exceedingly dry. The seed of none of the spring-sown small grains germinated and therefore no grain sorghums were planted.

TABLE IX.—*Results with Manchu Brown kaoliang at Bellefourche experiment farm, Newell, S. Dak., in 1909 and 1910.*

Year.	Data of test.	G. I. No. 171.	G. I. No. 261-3-1.	G. I. No. 261-3-2.	G. I. No. 261-3-3.	G. I. No. 261-3-4.	G. I. No. 261-3-5.	G. I. No. 261-4.	G. I. No. 328.	Average.
1909..	Planted	June 14	June 5	June 5	June 5	June 5	June 5	June 5	June 14	......
	Headed	Aug. 25	Aug. 23	Aug. 23	Aug. 24	Aug. 24	Aug. 23	Aug. 24	Aug. 25	......
	Ripened	Sept. 20	Sept. 18	Sept. 18	Sept. 18	Sept. 18	Sept. 18	Sept. 18	Sept. 20	......
	Days to mature	*98	105	105	105	105	105	105	98	......
	Yield ....bushels..	12.7	19.0	5.7	8.5	6.6	13.3	12.3	9.5	10.95
1910..	Planted	May 23	....	....	....	....	May 23	May 23	May 23	......
	Headed	Aug. 12	....	....	....	....	Aug. 12	Aug. 15	Aug. 9	......
	Ripened	Sept. 30	....	....	....	....	Sept. 30	Sept. 30	Sept. 30	......
	Days to mature	130	....	....	....	....	130	130	130	......
	Yield ....bushels..	7.66	....	....	....	....	13.22	12.45	8.62	†10.49
	Average yield for 2 years ...bushels..	10.18	....	....	....	....	13.26	12.37	9.06	†11.22

* Not fully mature. † Four selections only.

The three strains of Manchu Brown matured from 0.45 of a bushel to 1.2 bushels at the substation at Dickinson, N. Dak., in 1909, but were killed by frost without ripening in 1908 and 1910. In 1911 two strains ripened a little seed at Dickinson and also at Williston, in the northern part of the State. In Montana they have not yet been able to ripen successfully, though the results in 1911 with early strains from South Dakota have been quite promising. In parts of Idaho some good yields have been obtained by a few cooperating farmers. These strains give promise of value at the substation at Moro, Oreg., but it is too early to speak definitely as to their value there.

CULTURE OF KAOLIANGS.

The varieties of the kaoliang group are handled in all respects as are the other and better known groups of grain sorghums, viz., milo, durra, kafir, etc. The seeds of the kaoliangs are similar to those of the kafir varieties in size and shape, and the same adjustment of the planter will cause the same rate of seeding of both. They should be drilled in rows approximately 3½ feet apart, with a row space for each plant varying from 6 to 12 inches, according to climatic conditions. It is probable that under the conditions obtaining in the southern part of the Plains area in average or favorable seasons, a stand of one stalk to each 5 or 6 inches will give the best results. At higher elevations, or farther north, or in dry seasons thinner stands will be desirable. In regions subject to the frequent recurrence of dry seasons, and this probably includes all the so-called semiarid areas of the West, it is probable that a thin planting of a portion of the area devoted to grain sorghums each year will serve in a measure as insurance against a total loss of the crop. This practice has been followed in past years by a number of farmers with very good results. Like other grain sorghums, they should not be sown until the danger of spring frosts is well past.

SUMMARY.

The kaoliangs are a distinct group of grain-producing sorghums only recently introduced from eastern Asia.

They are found throughout the eastern half of the Chinese Empire, except in the low southeastern provinces, and extend northward and eastward through Manchuria and Chosen (Korea) to Japan. They are most abundantly grown in the northern part of this area, especially in Chihli and Manchuria.

No other sorghums are found in the region named except a variety of sorgo cultivated locally on and about Tsungming Island in the mouth of the Yangtze River. They are probably the descendants of varieties imported into China from India many centuries ago.

In the Orient the seed is used both for human and animal food and in the manufacture of liquor. The stalks are used for both fodder and fuel. In addition, the stems and leaves are used as material for thatching, fences, hedges, light bridges, and other building. They are also used in certain native manufactures, such as baskets, mattings, window shades, etc. The brush of some varieties is used for native brooms.

Varieties of kaoliang were introduced into this country as early as about 1866, and again at subsequent times, but were discarded after brief cultivation for sugar production. Since 1898, 49 direct and 3 indirect introductions from eastern Asia have been made, representing more than half as many distinct varieties.

Most of these introductions have been tested by the writer through a series of years and at a number of stations, from the agricultural and varietal standpoints. Since 1906, all introductions have been tested for grain production. Those giving any promise of value have been subjected to head-to-row breeding for pure strains.

Descriptions of the plant and seed characters of all the introductions and a description of the group as a whole are presented in this paper.

Twenty-seven distinct varieties of kaoliang are named and described for the first time, with complete keys for their separation.

The kaoliangs are good grain producers, though of little value for forage on account of their scanty foliage. They are not likely to displace any of the present groups of grain sorghums, such as the milos, durras, and kafirs, but on account of their earliness apparently have a distinct place of their own to fill in the more northern and more elevated parts of the dry-farmed areas.

The earliest variety, Manchu Brown, matures in 85 to 95 days in the southern Plains area, and in 100 to 110 days as far north as South Dakota. A number of high-yielding varieties mature in 110 days or less.

Of nine strains thoroughly tested at the Amarillo experiment farm from 1908 to 1911, inclusive, four produced average yields of more than 20 bushels per acre and the other five produced from 13.8 to 18.8 bushels per acre. The average yield for the nine strains was 19.7 bushels for the four-year period. The annual rainfall of the first three years was below normal and the seasonal rainfall was deficient in the middle two. Average yields of corn varieties under the same conditions were less than 5 bushels.

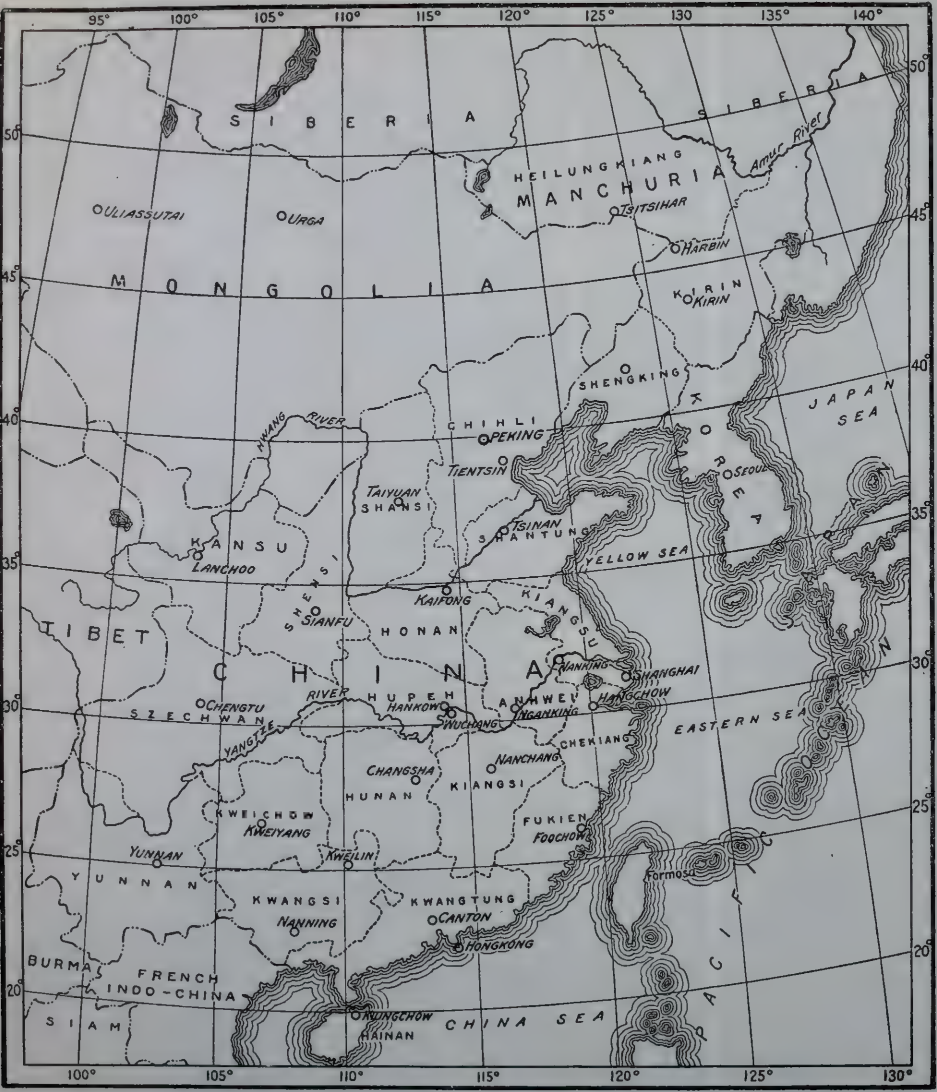
The strains of the extra-early Manchu Brown have been under test at various points in the Northwest during 1909, 1910, and 1911. At the substation at Highmore, S. Dak., they have produced an average yield of 13.7 bushels in the three-year period. At the Bellefourche experiment farm, Newell, S. Dak., four strains gave a two-year average of 11.2 bushels per acre.

Promising results are being obtained at other points at high elevations or in high latitudes.

DESCRIPTION OF PLATES.

PLATE I. Map of eastern Asia, showing the provinces and larger cities of China, Manchuria, and Chosen (Korea).

PLATE II. Spikelets and seeds of kaoliang varieties: *A*, Brill Blackhull, S. P. I. No. 17920 (G. I. No. 120); *B*, Korean Blackhull, S. P. I. No. 27553 (G. I. No. 412); *C*, Barchet Blackhull, S. P. I. No. 22912 (G. I. No. 310); *D*, Mukden White, S. P. I. No. 18610 (G. I. No. 190); *E*, Hansen Brown, S. P. I. No. 17921 (G. I. No. 121); *F*, Tientsin Brown, S. P. I. No. 17923 (G. I. No. 123); *G*, Kali Brown, S. P. I. No. 19187 (G. I. No. 193); *H*, Manchu Brown, S. P. I. No. 18518 (G. I. No. 171); *I*, Hankow Brown, S. P. I. No. 6604 (in part) (G. I. No. 326); *J*, Valley Brown, S. P. I. No. 22911 (G. I. No. 309); *K*, Ware Brown, S. P. I. No. 28027 (G. I. No. 421); *L*, Parker Brown, S. P. I. No. 28058 (G. I. No. 424); *M*, Shasi Brown, S. P. I. No. 21678 (G. I. No. 278); *N*, Peesan Brown, S. P. I. No. 17922 (G. I. No. 122); *O*, Chusan Brown, S. P. I. No. 23231 (G. I. No. 324); *P*, Tokyo Brown, S. P. I. No. 21677 (G. I. No. 277); *Q*, Choonchun Brown, S. P. I. No. 27554 (G. I. No. 413); *R*, Shantung Brown, S. P. I. No. 22010 (G. I. No. 293). (All natural size.)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Amur River
HEILUNGKIANG
MANCHURIA
Tsitsihar
Harbin
KIRIN
Kirin
SHENGKING
Uliassutai
Urga
MONGOLIA
Hwang River
CHIHLI
Peking
Tientsin
Taiyuan
SHANSI
Tsinan
SHANTUNG
KANSU
Lanchoo
SHENSI
Sianfu
Kaifong
HONAN
KIANGSU
TIBET
CHINA
Nanking
Shanghai
Hangchow
ANHWEI
Nganking
HUPEH
Hankow
Wuchang
River
Yangtze
Chengtu
SZECHWAN
CHEKIANG
Nanchang
KIANGSI
Changsha
HUNAN
KWEICHOW
Kweiyang
FUKIEN
Foochow
Yunnan
YUNNAN
Kweilin
KWANGSI
Nanning
KWANGTUNG
Canton
Hongkong
BURMA
FRENCH INDO-CHINA
SIAM
Kiungchow
HAINAN
CHINA SEA
Formosa
KOREA
Seoul
JAPAN SEA
YELLOW SEA
EASTERN SEA
JAPAN
PACIFIC
100°
105°
110°
115°
120°
125°
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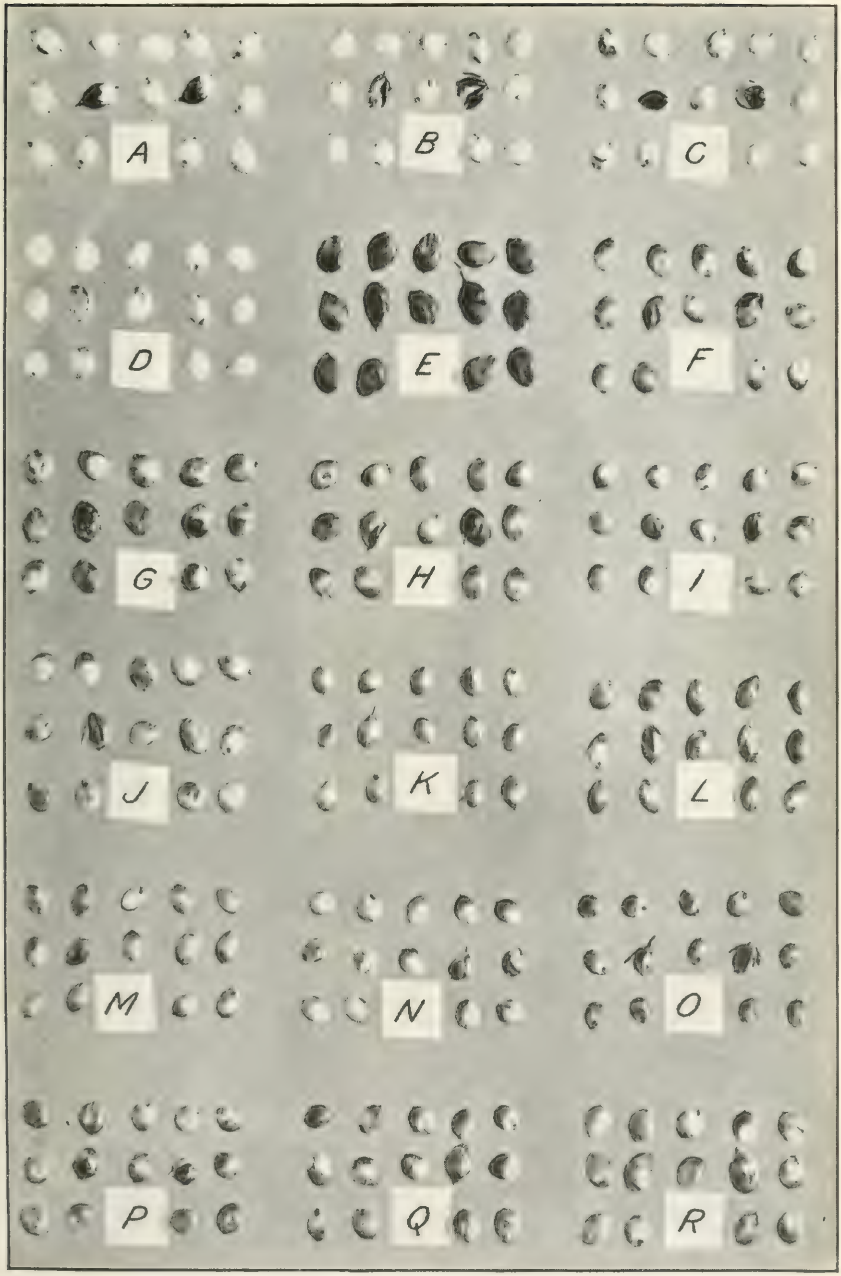
MAP OF EASTERN ASIA, SHOWING THE PROVINCES AND LARGER CITIES OF CHINA, MANCHURIA, AND CHOSEN (KOREA).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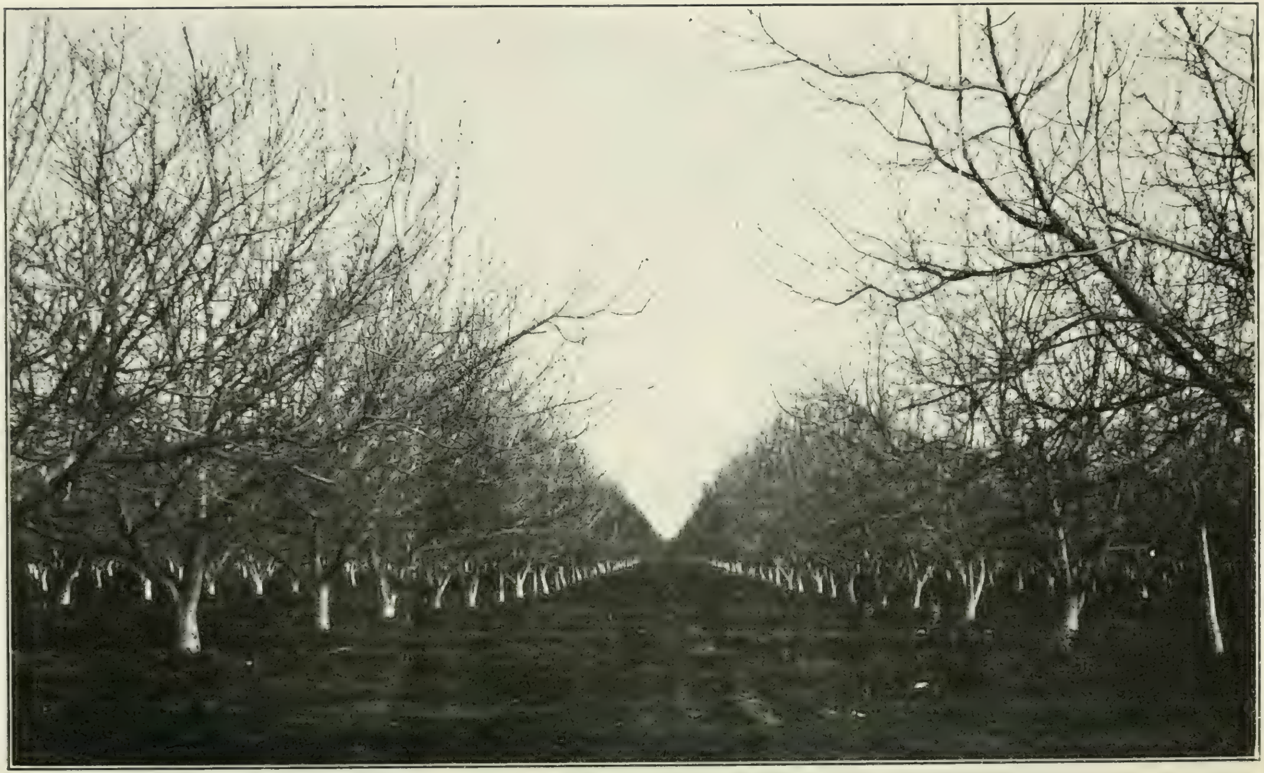
SPIKELETS AND SEEDS OF KAOLIANG VARIETIES.



A WELL-KEPT PERSIAN WALNUT ORCHARD IN CALIFORNIA, ILLUSTRATING THE THOROUGH TILLAGE THAT MAY BE READILY MAINTAINED AMONG LOW-HEADED TREES.

Issued February 27, 1913.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 254.

B. T. GALLOWAY, *Chief of Bureau.*

THE PERSIAN WALNUT INDUSTRY OF THE UNITED STATES.

BY

E. R. LAKE,
Assistant Pomologist, Pomological Collections.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., July 1, 1912.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 254 of the series of this Bureau the accompanying paper, entitled "The Persian Walnut Industry of the United States," by Mr. E. R. Lake, Assistant Pomologist, Pomological Collections, Bureau of Plant Industry.

The consumption and price of walnuts in the United States have greatly increased during the past decade, while the output of the home-grown product has been practically at a standstill, though rather extensive plantings have been made during the past ten years. The purpose of this paper is to explain in terms of actual orchard conditions why this apparent anomaly exists, and to present the best information obtainable as to the methods of making it possible to extend the area of successful cultivation of this nut. It aims further to answer the many questions now being propounded by a public that has been stimulated by alluring promises of marvelous incomes from orchard plantings of this tree.

Secondary aims of the author have been to describe the varieties of *Juglans regia* in such a manner as to make it possible for a layman to identify the known varieties and at the same time to lay the foundation for a systematic classification of this nut, to the end that a better knowledge of types and varieties will enable the planter to avoid many of the costly errors of the past.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—752.

THE PERSIAN WALNUT INDUSTRY OF THE UNITED STATES.[1]

INTRODUCTION.

The Persian walnut, more generally spoken of as the English walnut, came into cultivation in western Europe by way of Greece. The early Greek names "Persicon" and "Basilicon," applied to this nut, imply that is was either "brought from Persia by the monarchs of Greece or sent thither by the kings of Persia." Later the Greeks called it "Caryon, on account of the heaviness of the head which its strong odor caused."

The tree was really first brought into cultivation in Italy with the dawn of the Christian Era. Prior to this time the nuts were an article of commerce coming to Rome and other western marts under a multiplicity of names from Greece and the interior of Asia Minor. Particularly did the names used by early authors, like Grenoble or Sorrento of to-day, which designate localities or even shipping points, indicate the region known as Pontus in Asia Minor as the source of this nut.

As verifying the view that the walnut was not cultivated in Europe prior to the birth of Christ, Hehn in his book entitled "The Wanderings of Plants and Animals" says:

> In any case the want of settled names for these nuts proves that there was no general cultivation of these trees (almond, chestnut, and walnut) in Italy at the time of Cato, 234–149 B. C., though the walnut is mentioned several times by Varro, 116–27 B. C., and once by Cicero, 106–43 B. C., who relates that the daughters of Dionysius singed that tyrant's beard off with red-hot nutshells.

That the walnut was cultivated in other regions prior to the time the Romans introduced it into Europe is the opinion of De Candolle, who states that the Arabs knew it as Jouz or Jown at an earlier date.

---

[1] The writer desires to express sincere thanks to all those who, by contributions of data, specimens, or other material, have rendered valuable aid in the preparation of this bulletin. Especially to the following is he indebted for numerous favors: Prof. C. W. Beers, P. J. Berckmans Co., Leonard Coates, Dr. W. W. Fitzgerald, C. B. Franklin, Ferd Groner, L. C. Hall, Ely I. Hutchinson, F. A. Leib, M. McDonald, Dr. Robert T. Morris, J. B. Neff, George C. Payne, Pomeroy Bros., E. M. Price, Thomas Prince, J. G. Rush, C. C. Teague, Tribble Bros., the Vrooman Estate, E. G. Ware, and R. Wiltz.

The same author asserts that both the Bohemian name Oresak and the Biscayan name Encauria indicate that this tree was cultivated before the days of the Roman emperors. The Greek word "eros," which is found only once in the Bible, is held to be the term used to designate the walnut at that remote date.

It was during the imperial days of Rome, when it was commonly known as Jove's nut, Jupiter's acorn, or the nut of the gods, and used in the ceremonials associated with weddings, that the walnut was first distinguished by the name Juglandes. As an instance of the confusion that existed as to its name prior to this date, and which would appear to imply that only the crudest form of cultivation, if any at all, was accorded the walnut at that period, we find that "the popular name Jupiter's acorn, *Dios balanos*, which in Greek meant chestnut, has in the corresponding Latin form Juglans (Jovi-glans) the meaning of walnut."

The term "walnut" is a corruption of "Gall nut," the name under which the product of the trees of Gaul, the ancient name of France and adjacent territory, was marketed. It was probably first used by the Germans to designate the product as "the foreign nut."

The chief credit for bringing this tree under cultivation appears to belong to Vitellius, a Roman emperor, A. D. 39. Once established upon the soil of Italy it made rapid progress into the adjacent parts of Europe, being disseminated throughout the various territories covered by the Romans in their several northern and western invasions and remaining to bless the land as one of the beneficent incidents of devastating war after the conqueror had been conquered.

Though this tree, which is now known to science as *Juglans regia* and the product of which has been known successively or collectively to the trade as Persian, royal, Madeira, French, English, California, and even Oregon walnuts, was probably introduced into cultivation from Persia, it has been found growing in a state of nature in widely separated sections of the mountains of southwestern Asia, including northern India, southern China, Asia Minor, Afghanistan, the Caucasus, and in portions of southeastern Europe adjacent to Asia. Evidences of an even wider distribution of this tree in geologic ages is afforded by the fossils of the Tertiary period, which according to M. de Saporta show that it formerly existed in Provence and elsewhere in the southeastern portion of France. Other species of Juglans are catalogued from Jamaica, Spain, North and South America, Cuba, Japan, and Australia. At present it may be said that Juglans, through its various species, encircles the globe in the following manner: Eastern shore of Asia, *Juglans sieboldiana* and *J. cordiformis*, the Japan walnuts; western Asia and eastern Europe, *J. regia*, the royal walnut; eastern America, *J. nigra* and *J. cinerea*, the black walnut and the white walnut or butternut; western

America, *J. californica*, the California black walnut. There are two quite well-defined forms of *J. californica*. The northern form is a large tree, while the southern form usually assumes the habit of a large shrub. In the following pages reference is made to the northern form only. These species, together with the northern Chinese walnut (*J. mandshurica*), the Cuban walnut (*J. insularis*), the rock walnut of Texas (*J. rupestris*), three Mexican species, and those of South America afford evidence of adaptability to a wide range of environment.

DESCRIPTION OF THE PERSIAN WALNUT TREE.

The Persian walnut tree under favorable soil and climatic conditions is of large growth and long life. The following statements taken from the Gardeners' Chronicle, London, England, are cited as instances of the great growth and age to which this tree may attain:

> The famous old Beachemwell tree in England had the following recorded dimensions: Height, 90 feet; spread, 120 feet; height of trunk, 10 feet; diameter of trunk, nearly 10 feet; yield of nuts in one season, 54,000.
>
> The colossal tree that grew in the Department of Lot in France lived to be at least 300 years old, with a spread of 125 feet, a trunk 20 feet high and 14 feet in diameter. Its crop record was 15 bags a year on the average.
>
> The giant walnut that stood in Báidar Valley, near Balaklava, in the Crimea, reached the age of 1,000 years, and for a long time yielded annually 80,000 to 100,000 nuts, the joint property of five Tartar families, who shared its product equally.

In California, trees reputed to be approximately 140 years old, and with trunks 4 feet or more in diameter, are to be seen in the oldest missions. In some of the larger commercial orchards, from 35 to 40 years old, are to be found many trees with trunks 2 feet in diameter and a spread of 80 feet.

One of the successful growers of Carpinteria, Cal., Mr. C. B. Franklin, has said that he can see no reason why a walnut orchard in that locality should not continue to bear profitable crops until the trees are 150 to 200 years old, provided they are given good care and planted at least 45 feet apart on deep, mellow, rich soil.

In a more conservative view, however, F. E. Kellogg, of Santa Barbara, Cal., who has been intimately associated with the growth of at least two of the pioneer orchards of the State, is firmly of the opinion that the profitable life of a walnut orchard may be extended to 35 years if the trees are planted 50 to 60 feet apart on good, well-drained soil. This statement is not intended to imply in the least that individual and scattered trees may not bear profitably much longer. In fact, so far as authentic records are available, the data that pertain to exceptional longevity, enormous size, and extraordinary yield relate to single, isolated trees.

It may be said in this connection that the foregoing opinions of Mr. Franklin and Mr. Kellogg are based upon their knowledge of the conduct of seedling trees, grown under the conditions existing in southern California. Notwithstanding the somewhat divergent views as to the period of profitable fruitfulness and the distance between the trees, the consensus of opinion is to the effect that in vigor, size, and longevity the walnut exceeds any other of our commercial orchard trees. As a crop for long-time investment under a suitable environment, it offers attractions and inducements that are scarcely equaled by any other. Acre for acre, few individual trees are required, thus minimizing the loss from individual weaknesses. Modern methods of propagation assure a uniform product. The steady increase in crop output until the trees have reached a considerable age (at least half a century) insures an accumulating income. The comparative freedom from serious enemies save one, the blight, reduces very materially the probable loss of crop or the serious reduction of quality values.

THE CROP AND ITS USES.

NUTS AS FOOD.

The chief uses of the walnut are as food, mainly dessert and confections, though during the past few years, with the growth of the movement looking to the introduction of a larger element of vegetable products into our dietary, it has become an important element in the composition of many substantial table preparations. Large quantities of the lower grade nuts grown in Europe are expressed for oil, but very few of the nuts grown in the United States are used for this purpose. Walnut oil is highly esteemed in France and in some instances is used in preference to that of the olive. It is also rated high as a drying oil for artists' use. In Europe considerable quantities of young walnuts are used for making pickles and catchups, and though inquiries for such preparations have been made recently in the United States it is found that they are not produced in commercial quantities from American-grown nuts. As an article of confection the smaller walnuts find a ready sale, and large quantities are annually consumed.

The first effort by an American firm to put the cracked nuts upon the market in commercial quantities was made with the crop of 1910, when a Los Angeles firm purchased large quantities of culls at 2½ to 3½ cents per pound and after putting them through an improved power cracker sold about 25 tons of assorted meats. The market price was 35 cents per pound for the unbroken meats and 28 cents for broken meats. The shells were sold for fuel purposes at 20 cents per sack. The very dark, black, and blighted meats were disposed of as stock food, though steps have been taken to ascertain whether much of this low-grade material can not be used for making oil. In this connection an excerpt from the correspondence with this office of one of New York's largest and most exclusive importers and wholesale grocers, commenting upon the relative selling value of the American and French walnut products, may be pertinent to the topic under discussion.

> We were interested in the American cracked product last year (1910) principally because we could get it about two weeks before the foreign nuts arrived. This enabled us to distribute before the Thanksgiving holidays, which is a season of large consumption. Later in the year when the foreign nuts began to arrive we purchased chiefly of these, as they were more uniform in size, whiter in color, and more carefully assorted. Some years, as in 1910, it is found that, of uncracked nuts, the Grenoble, which is the best of the foreign nuts, is of higher quality than the home-grown nut; in other years it is the reverse. With the cracked nuts there is little, if any, choice as to quality, though there may be considerable in the respects noted above. Seasonal climatic conditions apparently have much influence upon the quality of the walnut.

Of this last remark something more may be said at this time, since seasonal variations in the quality of the product seriously affect the commercial stability of the crop. A notable instance of this character has been observed in the two crops of Manchurian nuts that were imported during 1910 and 1911. The importation of 1910 proved to be a fair quality hard-shell nut that cracked well, while the crop of 1911 was exceedingly disappointing, especially to the importers, who were losers by the transaction. The crop of 1911 cracked badly and, besides, yielded a larger percentage of poor-quality nuts as compared with the 1910 crop. Similar experiences followed the importation of Chilean nuts, which were formerly imported in considerable quantities. Even with the European crop there are wide variations in quality from one year to another.

OIL.

Thus far, little effort has been made to convert the American product into oil, probably owing to the fact that heretofore the quantity of inferior nuts has been very limited, or at least in the process of grading they have not been separated from the better quality nuts.

With the closer grading that will inevitably accompany an increased output, a higher price scale, and a more systematic handling of the crop there will be a distinct and appreciable quantity of culls that must be utilized; hence, the importance of an establishment for the conversion of the low-grade material heretofore of uncertain market value into products of recognized market ratings of moment.

For the past 20 years a grower in the southern California district has annually converted about 1,200 pounds of culls into oil for home use, and finds that each year it is increasingly appreciated as an article of food and medicine. As a result of this experience in expressing oil from the California product the following data are offered those who would utilize the culls. Good oil can be made only from sound nuts, though in commercial terms they may be culls. In other words, rancid, moldy, or partly decayed meats are not suitable for oil making. The nuts must be thoroughly dry before being expressed. Nuts, the kernels of which have been blackened through sunburn, are suitable for oil making, and such oil will be good, provided it is carefully clarified. The best oil is obtained from kernels that are plump and white, or at least of light color. Of the several varieties tested by the grower referred to, the Placentia has given the best results. A sack of the culls of this variety as offered in its home district, Orange County, Cal., weighs about 50 pounds and cracks about 25 pounds of meats, which expressed for 24 hours will yield 12 pints of excellent oil. For average culls, all varieties and one year with another, 25 pounds of meats yield 1 gallon of oil. Culls usually yield from 15 to 20 pounds of meats for each 50 pounds of nuts. Shriveled meats are as good as plump ones, but the quantity of oil in them is less. Oil experts have pronounced the oil from the soft-shell superior to that from the hard-shell varieties, though pound for pound the kernel yield is about the same. In any event care and cleanliness must be exercised in making the oil; otherwise the quality of the meats will count for naught. Under present conditions nuts are more profitably sold at 10 cents per pound than expressed into oil.

PICKLES.

Large quantities of immature walnuts are imported into the United States from Holland and England for use as pickles, catchups, sauces, and flavoring material. The nuts after being processed and barreled in brine are shipped in 70-gallon casks at a cost to the importer of $15 to $18, duty and freight included. There is no doubt that this part of the market demand for walnuts could be supplied by our own growers if on trial the cost of production permitted.

For pickling, the nuts are gathered when tender enough to be easily pierced by a large pin. At this stage they are entirely free from woodiness, a prime requisite for high-quality pickles. When picked the nuts are placed for nine days in a brine consisting of 4 pounds of salt to 1 gallon of water, renewed on the third and sixth days. On the tenth day the walnuts are removed from the brine and exposed to direct sunlight about two days until perfectly black. Sometimes the nuts are treated with dry salt instead of brine. This treatment, it is claimed, blackens them without exposure to sunlight. After the nuts are fully blackened they are placed in clean, dry jars and covered with hot, spiced malt vinegar, to each quart of which are added 2 ounces of whole pepper and 1 ounce each of allspice and bruised ginger root. Sometimes a few shallot onions are added to the boiling vinegar. After the jars are filled and the tops screwed down they are placed in a cool, dry room and in a month are ready for use, though they may be kept for 3 or 4 years.

Taken at the same stage of growth as for pickling and boiled in a rich sirup, walnuts are said to make a delicious and delicate sweetmeat.

DISTRIBUTION AND AREAS OF CULTURE.

CULTURAL RANGE.

As indicated by its variable natural habitat, the walnut may be grown over an extended area, though the profitable production of a high-class nut is confined to relatively narrow limits in a few widely separated regions—France, Italy, Germany, Austria-Hungary, Russia, China, Chile, and the United States. Though grown with commercial success in these countries, it is only in restricted areas of each that the choicer grades are produced, notably in the Grenoble district, France, in the vicinity of Sorrento, Italy, and in southern California.

That this nut is not grown successfully over a more extended area has been largely due to the absence of a thorough effort at improvement and adaptation, there having been practically no advance in varietal improvement since the origin of the Franquette, over 100 years ago. . Likewise, there has been only one notable instance of adaptation through selection, the Santa Barbara soft-shell, unless we take cognizance of the recent evidence of blight-resistant varieties in southern California. Within the past five years considerable impetus has been given the idea that the area of profitable walnut culture in the United States may be largely extended through the employment of other stocks than its own upon which to work the choicer and more hardy varieties of the Persian. Careful consideration of varietal requirements and adaptation by selection materially advance the view that the walnut may be commercially grown over a considerably wider area than was formerly supposed.

Various though not extended tests demonstrate that several of the leading commercial varieties of *Juglans regia*, the Persian walnut, when worked upon the American species *J. nigra* and *J. californica* may be successful in regions where formerly the Persian was a failure. The native stocks being more resistant to drought, heat, excess of moisture, alkalis, and unseasonable and severe changes in temperature, makes it possible to utilize a much greater range of soil and climatic conditions than has been deemed possible. Not only has the work with the American stocks given excellent results, but some very remarkable developments have followed the work of top and crown grafting upon certain hybrids originating in California, notably the Paradox and Royal. The Paradox is the offspring of a cross-pollination between *J. regia* and *J. californica*, while the Royal is the offspring of a cross-pollination between *J. nigra* and *J. californica*. These hybrids are characterized by an extraordinary vigor of growth, in many instances a year's growth of 12 to 15 feet as against half as much in the parents. Like the native species, these hybrids are hardier than the Persian walnut and not so subject to injury by early spring changes in temperature, which, through starting and checking a premature flow of sap, seriously damage the younger wood and blossoms. Grafted upon these hybrid stocks, the Persian walnut makes a remarkable growth and so far as tests with them have been made gives promise of early and abundant fruitfulness.

Serious defects appear in these hybrids in that while a few trees are reported prolific they are generally indifferent bearers and that the seedlings grown from the nuts vary greatly in vigor, in some instances not over 20 per cent being first class. Though this makes it necessary to grow a large number of seedlings for a small quantity of first-grade stock, some propagators consider the expense repaid by the exceptional vigor of the seedlings, surpassing the native blacks or the Persian. This view is strengthened by the observation of F. A. Leib, an extensive experimenter in the propagation of the walnut, who says:

> On the root depends the entire success of the orchard, and after an extended investigation we are convinced that the nuts of certain of our hybrids produce trees that surpass all others in sturdiness, adaptability, and rapidity of growth.

Of Mr. Leib's statement it may be said that, while he attaches great importance to the value of the root, or stock, and his words even imply that the whole credit of successful growth is due to the root, in his own practice he uses every precaution in the selection of scions, thus doubly insuring the production of a successful tree.

Mr. Payne, an observer, propagator, and grower of the walnut, is of the opinion that the merits of these hybrids are not yet fully determined. He says:

> I have noticed that in dry seasons the Paradox seems unable to furnish as much moisture for the development of its crop as the native California black growing under the same conditions. The nuts in the instances observed were considerably smaller on the Paradox root than on the native black, and I ascribe this result to a shortage in the water supply. Of the seedlings from the two hybrids, those of the royal are by far better, though they vary widely in general character as to vigor of growth, foliage, and resistance, while some of them when grafted refuse to unite with the Persian scion.

Mr. Payne's observation is not yet verified by other propagators, and it is possible that local conditions may have been a determining factor in the results observed by him. Should his observation as to the inability of the hybrids to endure drought become established a great part of their prospective value as stocks would be lost and the native black walnuts would be the sole reliance upon which to predicate the future extension of the area of walnut orcharding in the United States.

RANGE BY STATES.

Alabama.—"The walnut has not been grown in this State with any degree of success, except in a small way. So far as the product of the tree is concerned, it is usually strong flavored and early becomes rancid." (*P. F. Williams, Alabama Agricultural Experiment Station.*)

Arkansas.—"It is reported that an English walnut tree near Little Rock has been fruiting for several years, and it is recommended that it be tried further in the cotton belt." (*Arkansas State Horticultural Society, Report, 1910.*)

Colorado.—"One tree of the walnut, variety unknown, is successfully growing near Boulder, on the mesa near the foothills. There are no commercial plantings of this nut in the State to my knowledge." (*D. M. Andrews, Colorado.*)

District of Columbia.—In various parts of the District of Columbia are to be found large, thrifty seedling trees of the Persian walnut, but as far as examined, with one exception, the Barnes, the fruit is of indifferent size and quality. The climatic conditions are such that the trees do not bear regularly, though in the case of the Barnes it is reputed to be a good bearer, considering its immediate environment.

Florida.—"It is agreed on all hands that *Juglans regia* has failed in Florida. Many report that the trees die before bearing, though I have heard of some that bore. It is not recommended by any of the nurserymen of the State. *J. cordiformis* and *J. sieboldiana*, on the other hand, flourish well in north Florida and bear profusely. But the shells of their nuts are so hard and thick that there seems no prospect of their fruit rivaling the thin-shelled varieties of *J. regia* as a commercial product. Of the two, *J. cordiformis* seems preferable. I am unaware of any attempt to grow Japanese walnuts on a commercial scale in Florida." (*John Belling, Florida Agricultural Experiment Station.*)

Georgia.—"In 1908 and again in 1910 we made an extended inquiry of southern planters and nurserymen as to the success of the walnut in the South. After giving the reports of their various correspondents careful consideration we can not recommend the planting of the English walnut for commercial purposes this side of the Rocky Mountains." (*P. J. Berckmans Co., Georgia.*)

Indiana.—Though a few trees of the walnut are reported as successfully fruiting in Indiana, no especial effort has been made to give it a thorough trial. During the past year, however, one or two enthusiastic citizens of the State have undertaken to give the subject an extended experimental test.

Louisiana.—"About 15 years ago I planted grafted trees of several varieties of *Juglans regia* obtained from Felix Gillet, of California. The stock used was *regia* and these trees are now all dead, although the Mayette tree lived until two years ago and had attained a height of 20 feet, with a trunk 5 or 6 inches in diameter. This tree bore pistillate flowers for several years, but set no fruit. I now have a Mayette tree, top-budded on black walnut, which seems healthy, as does another of the Gillet varieties similarly worked. About the time that I planted the Gillet trees, Luther Burbank sent me a number of seedling trees of the Santa Rosa. One of these is still alive, but not more than 4 feet high. The native black grows and bears well here." (*B. M. Young, Morgan City, La., 1910.*)

Maryland.—"Maryland, except the two westernmost counties, and Delaware have been producing fairly good seedling Persian walnuts for 100 years, and there are many young, middle-aged, and very old trees with good bearing records. The soil and climate are adapted to hardy types of the Persian walnut, and a lively interest has been created in nut culture in these States in the last five years. A good many young walnut trees are being planted." (*C. P. Close, Maryland Agricultural Experiment Station.*)

Massachusetts.—"It can hardly be said that it [the Persian walnut] can be grown successfully in this State, although it is possible that a specimen growing in a particularly favorable location may live to become of considerable size." (*William P. Rich, secretary, Massachusetts Horticultural Society.*)

"It [the Persian walnut] does not succeed here [Amherst], and I know of no place in the State where it does." (*F. A. Waugh, Massachusetts Agricultural Experiment Station.*)

Michigan.—"I have a 16 or 17 year old Persian walnut tree that has borne every year for the past seven years. I also have trees 6 years old raised from nuts off this older tree, and I believe they will bear in another year. The parent tree is 26 inches in circumference and about 20 feet high." (*F. P. Andrus, Michigan, 1911.*)

Many other trees of this species, *Juglans regia*, have been planted in this State, if the records of nurserymen's sales may be relied upon, but we have been unable to obtain any record of their bearing.

Montana.—"The only English walnuts being tested in Montana, so far as I know, are a few varieties planted on our substation grounds at Corvallis. These have been out two years and have made a very unsatisfactory showing. Two or three trees out of 30 or 40 are alive at this time." (*O. B. Whipple, Montana Agricultural Experiment Station.*)

Nevada.—"To my knowledge, there is only one tree of the Persian walnut growing in the State of Nevada. This tree is somewhere between 15 and 20 years old and is growing near Franktown, Washoe County. It is about 60 feet high, with irregular branches, and bears abundant crops about once every four years and misses a crop about one year in seven. The nuts are smaller and have harder shells than the ones usually bought in stores." (*P. Beveridge Kennedy, Nevada Agricultural Experiment Station.*)

New Mexico.—"In New Mexico no record has been made of the planting of the walnut, yet *Juglans rupestris* grows naturally in several sections of the State, while *J. californica* is growing and fruiting successfully on the grounds of the experiment station." (*Fabian Garcia, New Mexico Agricultural Experiment Station.*)

New York.—Many trees of the Persian walnut are fruiting in this State, especially in the region tributary to Lake Ontario, about New York City, and on Long Island. Several of the older trees have yielded profitable commercial crops for the past 20 years. Recently many seedling trees have been planted throughout the State, and a few grafted trees are also being tried.

North Carolina.—Reports state that there are a few walnut trees growing indifferently in North Carolina.

Ohio.—"I do not know that any attempts are being made to grow the walnut upon a commercial scale in this State." (*W. Paddock, Ohio Agricultural Experiment Station.*)

Individual trees, however, have been reported as growing and bearing successfully in various parts of the State.

South Carolina.—"Though numerous plantings of the walnut have been made in South Carolina, there are no records of successful croppage. Even the particularly hardy *Juglans sieboldiana* is reported as not hardy enough for the conditions in this State, though *J. nigra* thrives and bears abundantly at an early age in various parts of the State." (*A. G. Shanklin, Clemson College, S. C.*)

From other sources it is learned that the tree appears to be hardy enough in some localities, but that it fails to set fruit.

Tennessee.—"A great many Persian walnut trees in this State are planted in gardens and lawns, but no one, so far as I know, has attempted an orchard of them. Some trees at Hermitage bore the first time about three years ago." (*C. A. Keffer, Tennessee Agricultural Experiment Station.*)

Texas.—"In 1903 we planted several trees of English walnuts at this station, but our results have been entirely negative in character. The trees made a very poor growth, and all but one died inside of four years. This one is still living, but has made only a low, scrubby growth—less than 5 feet—and has not fruited. Judging from our experience, I doubt if they are suited to this vicinity." (*W. S. Hotchkiss, Texas Agricultural Experiment Substation, Troup, Tex.*)

Virginia.—"So far as I am aware, the walnut is not grown in a systematic way in Virginia, though there are scattered seedlings in various parts of the State." (*H. S. Price, Virginia Agricultural Experiment Station.*)

Washington.—"The first walnuts planted in this part of the State were set out in 1896. In this first planting there were 15 trees (this tract has increased until at present there are 175 trees), all seedlings. They have grown vigorously and have been bearing good crops of nuts of variable quality since they were 6 and 7 years old. One of them, for which H. E. Van Deman suggests the name of Chelan, is considered to be a very promising variety. There are now about 30 acres of planted walnuts in this section." (*W. P. Shepard, Lake Chelan, Wash.*)

In the southwestern part of the State, especially in the vicinity of Vancouver, this tree has been growing and fruiting for approximately a quarter of a century. Not only have the trees of the Franquette and Mayette varieties been yielding excellent returns, but several local seedlings have been developed, two or three of which promise to be even better than their parents, the original varieties stated above.

In various parts of New Jersey, Virginia, and West Virginia vigorous, thrifty seedling trees are to be found. Several of these trees produce quite regular crops of nuts of more than passing merit. Most of them, however, yield nuts of inferior quality, and the chief value of the trees lies in the fact that they afford ample proof that the walnut can be grown in these various districts with measurable success. Top-working these trees with wood from hardy varieties of good quality would probably result in converting what is at present a crop of inferior quality and small value into one of choice quality and highest market price, though it is certain that much better returns would follow the top-working of the native stock in the same or similar localities.

CLIMATIC CONDITIONS REQUIRED IN WALNUT GROWING.

The walnut is quite sensitive to changes in temperature during the early stages of the vegetative period and while the tree is young. It demands a climate that is temperate, relatively mild, and invariable. It is averse to wide ranges of temperature and great humidity, and yet it will endure without damage considerable rigorous winter weather during its dormant period, and even during the annual vegetative periods of its later life it will tolerate climatic variations such as would greatly injure young trees.

This tree suffers less from the severe cold of winter than from the frosts of late spring or early fall. Intense winter cold may split open the trunks and large branches, but serious damage is unlikely where the native walnuts range or in the relatively mild climate of the Pacific Northwest, especially if the stocks used are the native black walnut. The walnut ranges over a considerable area, under varying climatic conditions, but the leading commercial varieties, especially in the United States, grow within a comparatively restricted climatic environment. In that part of France where the highest grade of the commercial product, the Grenoble walnut, is grown, the climate of spring and summer is somewhat cold and the winters rigorous. The mean annual temperature of Tullins in the valley of the Isere, the heart of the nut-producing area of France, is from 45° to 50° F. The rainfall for the district is most abundant during the spring and autumn and averages about 40 inches for the year.

The data in Table I, based on what French writers consider the relationship of climate to successful walnut culture, present a compact view of the climatic conditions in those districts of the United States which produce nuts in commercial quantities, as well as in a few districts where isolated trees or small orchards have borne profitable crops for several years. Considerable of the data given apparently warrants the belief that so far as climate is concerned the area of successful cultivation may be greatly extended; but climatic conditions are not alone essential to success. Quite as much depends upon the careful selection of varieties, and hardiness is only one of the qualities required. The ultimate product, the nut, must be of pleasing outline, regular and uniform in size, with a bright, rich, yellowish-colored shell that is thin and firmly sealed. It must possess a kernel that is crisp, sweet, light colored, and with little or no astringency or bitterness. It should be high flavored, fine grained, rich, and heavy. The tree must be a vigorous grower and must yield regular and abundant crops. It must be a self-pollinator and not too early. It must carry its blossoms through an extended period and be practically blight resistant.

TABLE I.—*Climatic and other data of important walnut-growing areas.*

Climatic and other data.	France.	California.			Oregon.		Pennsylvania.		New York.	
	Grenoble.	Los Angeles.	San Jose.	Santa Barbara.	Portland.	Albany.	Erie.	York.	Rochester.	Appleton.
Latitude	45° 30′	34° 3′	37° 20′	34° 23′	45° 32′	44° 35′	42° 7′	39° 50′	43° 8′	43° 20′
Elevation ... feet	1,000	287	95	130	32	224	658	385	498	270
APRIL.										
Temperature (° F.)										
Mean Monthly	51	60	56	58	51	51	45	50	45	44
Mean Maximum	68	70	....	67	60	59	56	62	53	54
Mean Minimum	39	49	....	48	42	42	42	39	36	35
Absolute Maximum	85	99	87	95	89	84	94	94	90	84
Absolute Minimum	27	38	29	38	28	30	16	16	11	16
Precipitation, inches:										
Mean	3	1.1	1.4	1.2	3.2	3.6	2.4	2.6	2.4	2
Annual	40	15.6	14.8	16.6	45.6	44.2	39.2	41.9	34.5	32.7
MAY.										
Temperature (° F.):										
Mean Monthly	58	63	60	60	57	57	57	64	57	55
Mean Maximum	68	73	....	69	67	69	65	73	66	65
Mean Minimum	40	52	....	50	48	46	49	50	47	44
Absolute Maximum	94	103	104	100	99	93	91	95	93	94
Absolute Minimum	32.2	40	32	40	32	32	31	31	28	26
Precipitation, inches:										
Mean	4.25	.5	.6	.4	2.4	2.6	3.6	4.3	3	2.9
JULY.										
Temperature (° F.):										
Mean Monthly	69	71	67	65	67	67	71	75	71	70
Mean Maximum	81	83	....	74	78	82	78	86	80	80
Mean Minimum	56	59	....	56	56	51	64	53	62	59
Absolute Maximum	97	109	100	96	102	103	94	107	99	98
Absolute Minimum	47	49	41	48	45	39	47	43	45	40
Precipitation, inches:										
Mean	4.33	....	0	0	.6	.3	3.1	4.1	3.1	4.2
AUGUST.										
Temperature (° F.):										
Mean Monthly	68	72	67	67	66	67	69	73	69	67
Mean Maximum	83	84	....	75	77	82	77	84	78	77
Mean Minimum	59	60	....	58	55	51	62	61	60	58
Absolute Maximum	101	106	101	97	97	101	94	102	97	97
Absolute Minimum	45	50	42	52	43	42	47	42	43	41
Precipitation, inches:										
Mean	3.8	....	....	0	.7	.4	3.2	4.1	2.9	3.1
SEPTEMBER.										
Temperature (° F.):										
Mean Monthly	50	70	65	66	61	60	64	66	63	61
Mean Maximum	55	82	....	74	71	72	60	77	72	71
Mean Minimum	51	57	....	56	51	48	46	55	53	52
Absolute Maximum	96	108	99	98	93	97	87	95	98	96
Absolute Minimum	37	44	37	49	36	32	23	20	34	31
Precipitation, inches:										
Mean	2.6	....	.2	.2	1.8	2	3.6	3.8	2.3	3.2

TABLE I.—*Climatic and other data of important walnut-growing areas*—Continued.

Climatic and other data.	France.	California.			Oregon.		Pennsylvania.		New York.	
	Grenoble.	Los Angeles.	San Jose.	Santa Barbara.	Portland.	Albany.	Erie.	York.	Rochester.	Appleton.
OCTOBER.										
Temperature (° F.):										
Mean—Monthly....	48	64	60	63	54	53	53	53	51	50
Mean—Maximum..	52	76	....	72	62	64	48	64	59	60
Mean—Minimum..	37	52	....	54	46	43	35	42	42	42
Absolute—Maximum	84	102	93	96	83	84	74	88	87	88
Absolute—Minimum	37	40	32	47	31	29	26	20	19	24
Precipitation, inches: Mean............	5.6	.8	.9	.8	5.6	3.4	3.8	3.1	2.8	2.4
DECEMBER.										
Temperature (° F.):										
Mean—Monthly....	34	56	50	56	42	41	43	43	29	30
Mean—Maximum..	37	67	....	68	47	47	39	52	35	36
Mean—Minimum..	35	46	....	45	37	37	26	34	22	23
Absolute—Maximum	64	89	78	84	65	63	70	77	70	66
Absolute—Minimum	65	30	22	32	3	18	−11	10	−11	−2
Precipitation, inches: Mean............	3	3.3	2.6	3.2	7.4	7.8	3.1	3.4	2.9	2.5
JANUARY.										
Temperature (° F.):										
Mean—Monthly....	36	54	48	53	39	39	27	33	24	26
Mean—Maximun..	42	64	....	64	44	45	34	42	31	32
Mean—Minimum..	32	44	....	44	34	34	20	25	18	19
Absolute—Maximum	63	87	78	84	62	62	73	68	69	59
Absolute—Minimum	−2	30	18	28	−2	10	−15	−1	−12	−2
Precipitation, inches: Mean............	2	2.8	2.7	3.7	6.6	6.7	3	3.1	3.2	2.6

Table I shows that southern California is remarkably exempt from freezing. Practically all the commercial crop in the United States is produced in this district with its mild, equable climate and deep, fertile soil. Extensive plantings of the Persian walnut are being made in other districts, notably in the Santa Clara, San Joaquin, and Sacramento valleys of California and the Umpqua and Willamette valleys of Oregon. Limited plantings are also being made in several other localities in the Pacific Coast States and in some of the Eastern States—New York, Pennsylvania, New Jersey, Delaware, and Maryland.

Though the Santa Barbara soft-shell walnut is the type of our present commercial output and the one variety most successful in southern California, its prestige may be due to the fact that no other variety has been generally tried in that district. Its early and continued financial success prevented the development of any better variety until the time of the blight invasion a few years ago. Now there is a decided effort to find a variety with the merits of the soft-shell that shall be blight resistant. It is quite possible that out of this inquiry, which is certain to be an exhaustive one because of the great value of the crop, there will come a new type, or at least one more definite and uniform. While other districts are selecting hardier varieties, southern California, in seeking those that escape the late spring frosts, aims to insure not alone the production of a crop, but also to provide immunity to blight. By a judicious selection of late-vegetating varieties and by top-working upon native stocks, growers may successfully produce choice varieties of Persian walnuts under a much wider range of climate and soil than formerly was possible. Types like the French Franquette, Mayette, and Parisienne appear to be worthy of extended trial in the valleys of northern California, the higher elevations in the interior of the same State, and the western valleys of Oregon and Washington. Among promising varieties worthy of trial in this territory are Eureka, Prolific, Treyve, and Meylan. Certain growers report that Treyve and Meylan are rather shy bearers, which may prove a serious defect in these otherwise good varieties. Types of more or less uncertain parentage, as the Cumberland, Hall, Holden, Milbank, Mount, Nebo, Pomeroy, and Rush, appear to be especially adapted to New York, Pennsylvania, New Jersey, Delaware, and Maryland, and the effort now being made to propagate the more promising of them upon the eastern black walnut bids fair to greatly stimulate the interest in walnut culture in portions of the eastern United States. There is little reason to doubt that several of these varieties may be successfully grown and fruited if proper provision is made for pollination.

To what extent the introduction of grafting upon these hardy stocks will change the practice of growing seedlings from fruit of mediocre merit is as yet uncertain. Very little grafting has been done where only individual trees or small groups about the home grounds are grown from hardy seedlings, as in Michigan, Ohio, Indiana, Illinois, New York, Connecticut, New Jersey, Delaware, Maryland, West Virginia, Virginia, North Carolina, South Carolina, Georgia, Texas, Colorado, and Idaho. In Texas and Maryland considerable interest is being awakened through the work of private experimenters and the experiment stations. The range of country covered by the above list of States shows the possible area over which the walnut may be grown. In most instances only very indifferent success commercially has been attained with seedling trees of the Persian walnut. California and Oregon are exceptions, and here the day of the seedling tree is past save as an effort to obtain a new variety. The orchards of the future will be grafted trees of varieties selected to meet the local climatic environment.

SOIL REQUIREMENTS FOR WALNUT ORCHARDING.

The walnut delights in a deep, moderately cool, moist soil, mellow, alluvial, and rich in humus, but it succeeds well upon clay loams, sandy loams, gravelly loams, or friable clays (such as the so-called shot clays of the Pacific Northwest) when the surface soil is well drained and possesses a liberal humus content and the water table is at a depth of 16 or more feet. For the growth and maintenance of large, long-lived trees, one thing is essential: The soil must be deep, 2 to 3 or more feet, and have a porous subsoil from 8 to 12 or more feet deep, and in no instance should hardpan, bedrock, or impervious clay be at a less depth than 16 to 20 feet. The most vigorous and productive walnut orchards in France and California are found upon the deep, cool, well-aerated, alluvial soils of the valleys, and especially upon slight elevations above the main valley floor.

A moderate lime content is a desirable feature of any soil upon which the walnut is to be planted for commercial purposes. Soil that is held to be good for orchard and garden crops may be considered suitable for walnut trees, provided it is sufficiently deep, well-drained as to air and water, and of an elevation sufficient to escape the early autumn and late spring frosts.

A soil composed of small to medium sized gravel mixed with 15 to 40 per cent of fine sand and clay and 1 to 2 per cent of lime makes an excellent host for the walnut tree. The reddish brown alluvial soils of the Pacific coast, rich in iron oxids, when overlying a gravelly, sandy subsoil, are among the best for walnut growing, as they are usually cool and supplied with moisture which thorough tillage and the use of the soil mulch will conserve. These soils are friable and rather coarse grained, fertile, well aerated, deep and retentive, and very responsive to all active tillage.

In the Eastern States, so far as present data show, it may be said that the Persian walnut flourishes on all soils upon which the black walnut is found, and under favorable conditions on some others. In fact, reports from 9 or 10 States say that the walnut will grow satisfactorily upon any good soil if it is deep, sufficiently well drained, aerated, and possesses a low water table. Sandy loams, clay loams, gravelly loams if not too open, and sedimentary deposits are all, separately or mixed, equally suitable for the growth of this tree.

FACTORS IN LOCATING A WALNUT ORCHARD.

LOCATION.

In some respects the problem of locating a walnut orchard is not difficult. The product being extremely hard, compact, and long keeping, it is not essential that railroad facilities be in the immediate vicinity. Wherever there are passable roads, suitable soils, a fit site, and congenial climate a walnut orchard may be located with quite as much assurance of success as if it were close to a great transportation system or a ready market. If, during the first few years, the grower desires to raise intercrops their importance may be a factor in determining the location. The selection of varieties and the necessity of early marketing affect the problem, since dealers desire the product for the Thanksgiving market. Labor for harvesting has likewise to be carefully considered, especially where large areas are contemplated or where fall rains occur during the period of harvest. Should the walnut harvest come at the same time with other crops it seems desirable that the location should be near a center of population.

SITE.

In a general way it may be said that the walnut requires a site that will insure it protection from excessive heat, cold, wind, drought, and moisture. An ideal site is one that affords protection against the undue stimulating influences of warm days in early spring, the ravages of early autumn frosts, the desiccating effects of drought, the distress of a water-logged subsoil, and the parching heat of a midsummer sun. To what extent it may be possible to secure all of these desirable features in a particular site will depend upon the prevailing climatic and topographic conditions.

European writers consider a western exposure best, and gentle slopes of moderate elevation better than valley floors, higher hills, or plains. Especially should the lower levels of the valleys be avoided if the air is damp and the soil cold and heavy. While the walnut demands a soil with plenty of water, it requires at the same time a dry atmosphere without too much heat. In some instances the fault of a site may be overcome through the selection of suitable varieties. Where an intense summer sun would damage the nuts by burning, partial or entire exemption may be secured through the selection of a variety with an abundance of foliage; where late spring frosts occur injury is reduced to a minimum by selecting late varieties. Only when it is impossible to secure a first-class site should one give a moment's consideration to other than the best varieties, such as by early maturity, prolificness, self-fertility, or a heavy oil content may yield a crop of substantial value.

In the coast valleys of southern California damage from spring and autumn frosts is almost unknown, though occasionally trees growing too late in the autumn have been injured by an unusual cold wave. Cold autumn rains rarely damage the crop and are not to be considered a serious menace. Under such conditions little difficulty will be encountered in selecting a site. Any place that presents a suitable soil and water supply is acceptable. Low-lying valley lands and river bottoms, so long as their soils are not cold with excess of water, and gently rolling lower benches are equally suitable. Almost universally the more fertile soils of this region occupy the floors of the valleys and the river bottoms. Occasionally, however, the soils of the lower levels are close, heavy, cold, and poorly drained, so that the more suitable site for a walnut grove may be upon the first benches or at the head or margin of the valley floor. In the interior valleys and plains so little has been done with the walnut that anything in the way of specific direction as to site would be mere assumption.

Early and late frosts, hot, dry winds, and intense sunlight are of such importance that each planter must decide his own case according to the facts before him. Protection from winds, excessive heat, and extra-seasonal frosts should be chief considerations in all plantings. As a protection against winds one may select the lee side of a mountain or timber belt; against frosts, an elevated site with good air drainage or a wind-protected vale where orchard heaters may be used in case of need; and against excessive sunlight, trees with dense foliage or nuts with heavy hulls, or both. For the information of the inexperienced it should be said that upon this phase of the subject few facts are at hand, as the possibility of cultivating this tree with commercial success under the conditions that exist in the interior valleys of California has received attention only within the past few years.

In the more northern Pacific coast regions, especially in the valleys of western Oregon, which appear particularly well adapted to the production of a high-grade nut, it is necessary to exercise considerable care in the selection of a site. These valleys have equable climate, congenial soil, and abundant moisture, coupled with sufficient drainage, but occasional frosts in late spring or early autumn damage the crop or even the trees if not properly situated. In some seasons the fall rains retard the maturing crop and increase the staining of nuts from contact with the soil. A judiciously chosen site should provide thorough soil drainage, generous exposure to direct sunlight, and a free circulation of air.

VARIETIES AND TYPES OF WALNUTS.

To-day the leading walnut upon the world's markets is the Grenoble, grown in the valley of the Isere, a river having its source in the foothills of the western Alps in southeastern France. Strictly speaking, the Grenoble nut means the Mayette variety, though the term sometimes includes the Franquette and Parisienne varieties grown in the same section. The leading product of the American walnut orchards, supplying about one-third of the quantity consumed in the United States, is the Santa Barbara, a soft-shell nut that originated with Joseph Sexton, Goleta, Cal., some 40 years ago and is reputed to be a seedling from a nut imported from Chile. Though this variety (more properly type, if one considers uniformity of product) constitutes something like 90 per cent of the home-grown walnuts marketed in the United States, several other varieties possess high merit. Some of these varieties, notably the home-grown Franquette, enter the American market under their own names, and it is quite probable that several distinctive American varieties will be marketed in a few years. Herein is one of the most promising aspects of walnut growing—the development of the industry beyond a general product. As the apple orchardist during the last decade has passed from a grower of apples in general to a grower of specific varieties, such as the Winesap, Esopus, etc., so the walnut orchardist may anticipate a type of orcharding wherein the grower becomes a specialist, a producer of specific varieties for definite purposes or because of a special environment.

The possibility of producing and marketing a distinct type of nut, having its own particular merits or qualities, will add many attractions to an industry that heretofore has offered no especial incentive to the intelligent person looking for opportunity to develop a special product. Such development of varieties will be a necessary result of the climatic requirements of the northern Pacific coast, quite different from those giving the best results in southern California, and still more so from those yielding partially satisfactory results in the Eastern States. That it is possible to develop varieties particularly adapted to the requirements of these separate districts is no longer considered doubtful by advanced workers in nuciculture. To this end substantial aid is expected from investigations now being conducted by nurserymen and enthusiastic growers with the late-blossoming varieties and hardy stocks in both the Eastern and Pacific Coast States. The California experiment station at Whittier deserves especial credit for arousing interest throughout the State in the effort to develop better varieties, to improve the methods of culture, and to plant grafted trees instead of seedlings.

Of the extended list of varieties of Persian walnuts that have been catalogued, few are of commercial importance in the United States. In this survey of walnut growing, it has been the purpose to consider every variety that appears to possess active or latent possibilities of adaptation and development by which the area of cultivation may be extended. So far as it has been possible to procure home-grown specimens of the several varieties, they have been subjected to critical examination and comparison in order to establish a uniform and amplified description, such as would enable even a novice to identify typical specimens of varieties of record. It has been impossible within the available time and means to procure specimens of all varieties reported to have been grown in the United States, and in a few instances we were unable to procure sufficient specimens upon which to base a complete description, e. g., of Cosine, Honeydew, Nebo, and Parry. The first, Cosine, is an indifferent variety, reputed to have originated in Oregon from a Chilean nut, and is of historic value only. The other three, and especially Honeydew, are worthy of trial. Nebo is an eastern seedling and may possess little merit for Pacific coast planting. Honeydew is a superior Mayette, so far as outward appearances indicate, and promises to be especially suited to Pacific coast conditions, though it may thrive in the Eastern States when grafted upon the eastern black walnut.

The descriptions offered at this time are necessarily incomplete, since they are based chiefly upon specimens of the crop of 1910, which was a very severe year and an imperfect development of the fruit was generally prevalent. The hope is expressed at this time that originators and growers will advise the Department of Agriculture of the advent of new varieties or of changes in the conduct of established varieties as they are subjected to the influence of new environment, so that deficiencies in the descriptions may be corrected and printed later, with others that may then be given.

Nuts of the cultivated varieties of Persian walnut vary greatly in size, shape, color, and minor characteristics. Those grown in the United States are separated quite readily into varietal groups or types—Bijou, Mayette, Franquette, Chaberte, Santa Barbara, Sorrento, etc.—and for the purpose of facilitating classification 20 such types have been defined. So far as known this is more complete than any previous grouping of the walnut. Classification requirements are apparently best met by the French system, comprising five leading divisions as determined by (1) region, (2) location of growth, (3) precocity, (4) thickness of shell, and (5) use. Of the various groups, the following may interest American planters:[1]

Varieties for lower level lands and plains: Chaberte, Common, Parisienne.

Varieties for hillsides and bench lands: Common, Cornes,[2] Chaberte, Fertile, Franquette, Hardshell, Marbots,[2] Mayette, Saint John, Vourey.

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[1] Arthaud-Berthet, J. Culture du noyer en France. Annales de l'Institut National Agronomique, sér. 2, t. 2, 1903, pp. 19–144, 7 pls.

[2] Commercial types rather than specific varieties.

Varieties for dessert: Cornes, Fertile, Figeac, Franquette, Gauteron, Marbots, Mayette, Meylan, Nave, Parisienne, Thinshell, Vourey.

Varieties for confections: Candelon, Careme, Chaberte, Common, Small Round.

Varieties for oil: Bijou, Candelon, Careme, Chaberte, Cluster, Common, Double Kernel, Hardshell, Noisette, Saint John.

CLASSIFICATION AND DESCRIPTION OF VARIETIES.

The tentative scheme of classification here given is offered with a view to facilitate the study of varieties and types of the walnut grown in the United States, and may be of service in the effort to extend the area of successful walnut culture. The basis of the scheme is the structural resemblance of the nuts, an arbitrary grouping, only incidental consideration being given to botanical relationships; but this classification does, in effect, group varieties closely related, since the form and structure generally indicate varietal peculiarities within the several groups. In the future it may be possible to classify the varieties according to a more exact and natural scheme, but with the data available it appears impossible at present.

Names in italic indicate varieties which are types of their respective groups. No type is designated where, so far as ascertained, none exists in American orchards. The word "type" after the name implies that the variety described is the standard of that group. The name usually agrees with the type name, though in the case of Persian Long, Marbot, Sorrento, and Cahor there are no type varieties growing in the United States, so far as known.

SCHEME OF CLASSIFICATION.

Bijou: A'Bijou, Acme, Alpine, Barnes, *Bijou*, Calavette, Glady, Hall, Klondike, Mammoth, Payou, Peerless, Willson.

Cahor: Chelan, Ward.

Brantome: Hays.

Chaberte: *Chaberte*, Drew,[1] Papershell.

Chinese: *Changli*.

Cluster: *Cluster*, Concord, Fertile (Gillet seedling).

Common: Weaver.

Fertile: *Fertile*, Late Fertile, Mammoth Fertile.

Franquette: Franmay, *Franquette*, Mayquette, Vourey[2] (short).

Hybrid: Barthere, Paradox, Royal, Vilmorin.

Lalande: Derby.

Mayette: Bennett, Chicoette,[3] Columbus,[3] Fertile (Gillet seedling), Grand Noblesse, Honeydew, *Mayette*, Mayette Blanche.

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[1] Based upon illustration and description by Arthaud-Berthet, but not conforming to the type illustrated in Plate VI.

[2] Specimens of this variety sent in by the late Felix Gillet do not conform to the French type as described and illustrated by Lèsourd.

[3] Doubtful.

Marbot: Holden, Mount, Pomeroy.[1]

Meylan: *Meylan.*

Mission: *Mission.*

Montignac:[2] Lea.

Nave: Ellwood.

Parisienne: Milbank, Nebo, *Parisienne*, Rush, Sinclair, Treyve.

Persian Long: Chase (2), Eureka, Hale, Kaghazi (long), Keesling, Prince, Prolific, Stocktonian.

Santa Barbara: Chase (1), Ford, Journeay, Lane, Neff, Placentia, *Santa Barbara*, Santa Rosa, Sexton, Teague.

Sorrento: Dean, Hubbard.

Not Classified.—The writer has been unable to see either specimens or written descriptions of the following varieties; hence, no attempt is made to group them: Ford's Mammoth, Hightstown, Longbeaked, Mobart, Parry, Poorman, Thinshelled, Volga, Weeping.

DESCRIPTIVE LIST OF VARIETIES.

In the following descriptive list of varieties of the Persian walnut the statements as to size are made by comparing the American-grown nuts with the average French Mayette. Upon this basis Cumberland and Rush are approximately typical of a medium-sized nut.

Technical terms used are chiefly from European writers and some have been adapted from modern systematic botany. For convenient reference a few are here defined:

Appressed. Ribs of the sutures not above the general surface of the shell.

Convolutions. The waving or folded rolls of the margins of the kernel.

Diaphragm. The thin, woody, membranous tissue that more or less distinctly separates the halves of the kernel.

Equator. An estimated horizontal region midway between the apex and the base, though in some instances, when considering the location of the pits at the sutures, it is deemed to be somewhat above or below a median line.

Flange. The face of the suture, varying in width with the different varieties.

Longitudinal lines. The more or less pronounced lines which pass from base to apex over the shell midway (or nearly so) between the sutures.

Mucronate. Having a suture tipped with a short, sharp, thin point.

Pellicle. The thin membrane that covers the kernel. It is the seat of the astringent and bitter principles that mark many of the American-grown walnuts.

Sutures. The more or less ribbed lines along which the two halves of the shell unite.

A'Bijou.

A name used by John Rock to designate a seedling of Bijou quite similar in form and size to the variety herein described as Klondike (p. 44), but having a much richer yellowish shell.

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[1] The two lots of Pomeroy walnuts received for comparison differed so widely in general character that it is impossible to assign this variety satisfactorily to any one group. Nuts from one of the parent trees, crop of 1910, resemble the Common nut of France, while the nuts from seedling trees of the parent Pomeroy trees resemble very closely the Figeac type. Until a more extended study of this variety is made it must remain unclassified, though Dr. Morris has stated that in his opinion it is a Marbot.

[2] After Lesourd.

Acme.

A large nut of the Bijou type, similar to the Willson; originated in the same section and at about the same time. Said by the introducer to be blight resistant.

Ailanthus Leaved.[1]

Probably a synonym of *Juglans sieboldiana.*

Alexis.

A seedling originating on the property of Alexander Smith, Cecil County, Md. The tree is very vigorous and productive. The nut is reputed to be large and good. Exhibited at the meeting of the Northern Nut Growers' Association, Lancaster, Pa., 1912.

Alpine.

Bijou type; large; broadly oblong, angular and slightly tapering toward the base; base obtuse and rounded; apex obtuse with short mucronate point; sutures appressed toward the base and only slightly ribbed toward the apex, pitted at the equator; flange very firmly sealed; shell grayish yellow, roughened with numerous deep, irregular, variable pits and protuberances, usually two or more longitudinal lines well defined. *Origin:* France; specimens grown by Felix Gillet, crop of 1904.

Lelong, in his treatise entitled "California Walnut Industry," published in 1896, writing of this variety, says: "A new and very large variety that originated not long ago in the Alps Mountains of France. Next to the Mammoth it is the largest walnut grown on my place. Though the shell is rough, it is thin, and the meat sweet and filling well the shell."

Andrus.

A seedling originating with F. P. Andrus in Michigan. It is reputed to be a hardy tree on its own roots in that State.

Ash Leaved.

Synonym of Cutleaf.

Barnes.

Bijou type, modified; size above medium; obovate to roundish or occasionally nearly oblong; strongly four-angled, many specimens will stand quite erect upon apex; base obtuse to acute; apex obtuse-truncate, small mucronate tip usually depressed; sutures appressed, more or less depressed toward the base, usually two to four rather large, deep, widely separated and commonly oblique pits at the equator; flange narrow or even very narrow, firmly sealed; shell rather thick, grayish brown, sometimes slightly mottled, moderately smooth, though a few deep depressions and a few pronounced protuberances are present, veining ample, longitudinal lines usually well defined; diaphragm firmly shouldered, rather strong, and inclined to be persistent; kernel full, convolutions even, quite regular; pellicle brownish with slightly darker veins which are broad but not numerous, astringent; flesh firm, crisp, rather dry, fine grain; flavor sweet, pleasant; quality fair to good. *Origin:* Seedling trees growing upon the grounds of Theodore Barnes, in Washington, D. C.; first called to public attention in an exhibit at the Convention of Northern Nut Growers, Ithaca, N. Y., 1911, by T. P. Littlepage.

Barthere.[2]

A French variety introduced into the United States in 1871. Of this variety Mr. Gillet, the introducer, says: "A singularly shaped nut, elongated, broad at the center and tapering at both ends; the shell is harder than that of other varieties."

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[1] Georgia Horticultural Society, 1900.

[2] Catalogue, Barren Hill Nurseries, 1887–88.

Bennett.

A variety reputed to have been produced from a nut purchased in New York City in 1874 by James L. Bennett, and grown upon his property at Unionville, Orange Co., N. Y.

Bijou.

Type; very large; oblong to more or less obovate and angular; base obtuse; apex obtuse to depressed, mucronate tipped; sutures appressed or even depressed especially toward the base, pitted at the equator and toward the apex, frequently pits form a continuous line over half the length of the suture; flange narrow, usually firmly sealed; shell brown, thickened by ridges and irregular protuberances, and strongly roughened by numerous pits and depressions, longitudinal lines occasionally well defined; diaphragm weak shouldered, thin, and scarcely persistent; kernel quite full, rather plump, convolutions moderate, very irregular; pellicle brownish yellow, dull, astringent; veins rarely noticeable; flesh moderately oily; flavor sweet, mild; quality good. *Origin:* Europe; specimens grown by Ely I. Hutchinson, crop of 1910. (See Pl. III.)

Burbank.

Synonym of Santa Rosa.

Calavette.

Bijou type; originated with E. M. Price, Westpoint, Cal. It is a cross between Bijou and Fertile. It is not recommended for sections in which late frosts occur, though it originated at an elevation of 3,000 feet in the Sierra Nevada Mountains.

California Papershell.

Originated by Felix Gillet from a nut borne on a grafted Chaberte tree. It is, therefore, a second generation Chaberte. The nut is only medium in size; shell very thin and almost white; kernel full fleshed, exceedingly sweet and nutty.[1]

Chaberte.

Type; medium; oblong; base obtuse; apex obtuse, mucronate tipped; sutures appressed to very slightly ribbed, usually pitted at the equator; flange variable, usually broad, very firmly sealed; shell brownish, thick, slightly roughened with a few depressions and protuberances, longitudinal lines well defined; diaphragm firmly shouldered, thin, but somewhat persistent; kernel full, fairly plump, convolutions moderate, variable; pellicle brownish yellow, dull; scarcely astringent; veins very noticeable; flesh oily, rich; flavor mild, sweet; quality very good. *Origin:* France; specimens grown by Ely I. Hutchinson, crop of 1910 (Pl. VI).

A variety held to be of very general merit. In France it is considered a very suitable variety to plant on both foothills and valley floors; it is valued in Europe as rich in oil and for confections. It is rather late in vegetating in the spring. An objection to the walnut for confectioners' use is that the kernels are too large, but our planters may find it worth while to ascertain if the Chaberte or a similar nut can be advantageously grown in this country.

Changli.

(S. P. I. No. 17943.) Chinese type; large; roundish oblate; base obtuse truncate; apex obtuse to retuse truncate without point or tip; sutures appressed toward the base, slightly ribbed, broad and rounded above, more or less pitted at the equator; flange very firmly sealed; shell brownish yellow, somewhat roughened by depressions, usually slight, with few pits, longitudinal lines, usually light and rather inconspicuous, though rarely altogether absent. (See Pl. II.) *Origin:* China. Specimens collected in the vicinity of Changli, Chihli Province, China, by F. N. Meyer.

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[1] Lelong, B. M. California Walnut Industry. 1895–96.

Mr. Meyer, in Bulletin 204, Bureau of Plant Industry, entitled "Agricultural Explorations in the Fruit and Nut Orchards of China," writing of this variety together with others produced in the same locality, remarks: "In the vicinity of Changli, Chihli Province, there are some walnut orchards in which the trees vary to a remarkable degree. Some produce small, hard-shelled nuts of poor flavor, while others bear fine, large nuts, with a really fine flavor, and having shells so thin that they can be cracked with the fingers like a peanut. Between these extremes one finds many gradations in hardness of shell, size, and flavor. It is very likely that some kinds of these Chinese nuts may prove to be much hardier than our present Persian strain of walnuts and in all probability they will thrive especially well in certain sections of the southern Rocky Mountain region."

This Chinese type of walnut Mr. Meyer has designated as *Juglans regia sinensis*. The type is admirably illustrated in the above variety, to which, though reported by number, the writer has given the name Changli, to designate its source. As already indicated, the nuts are large, flattened at the ends, inclined to smoothness and full roundness, with sutures marked by peculiar broad and smooth, rounded ribs. The age of the specimens prevented determination of the value of the kernel at the time of describing the nut, but on the strength of Mr. Meyer's statement that the fine large nuts possess a really fine flavor, steps have been taken to import wood of this variety and others from the same district.

Chase (1).

Santa Barbara type, closely resembling the More form; large; broadly oblong and angular; base rounded, occasionally acute; apex obtuse or acute and strongly pointed; sutures usually strongly ribbed, rarely pitted at the equator; flange narrow, very firmly sealed; shell thin, grayish brown, roughened by various irregular depressions, longitudinal lines not infrequent; diaphragm almost weakly shouldered, thin, yielding, rarely persistent; kernel full, rather plump, convolutions moderate, even; pellicle rather dark, glossy, astringent; veins dark and rather well defined; flesh rather coarse, oily, rich; quality fair. *Origin:* A seedling from nuts imported from France by Felix Gillet and planted by Mr. Van Vorce near Whittier, Cal., in 1886; specimens supplied by A. R. Rideout, crop of 1910 (Pls. VI and X).

Chase (2).

Persian Long type; this type differs from the preceding in that the nuts are more narrowly oblong, smoother, and more regular, with appressed or very slightly ribbed sutures that are usually less firmly sealed; specimens supplied by A. R. Rideout, crop of 1910 (Pl. X).

This variety is indorsed by the University of California as worthy of extended trial by those in search of blight-resistant varieties.[1] The variety does not appear to be firmly fixed as yet, or else more than one form is being propagated.

Chelan.

Cahor type; medium to slightly above; oblong; base obtuse to slightly rounded; apex obtuse to acute with slight point; sutures very moderately ribbed, equatorial pits variable, often absent; flange very thin, firmly sealed; shell very thin but rather firm, yellowish or grayish brown, roughened with numerous irregular depressions and furrows; diaphragm weakly shouldered, thin, and scarcely persistent; kernel full, rather plump, convolutions moderate and variable; pellicle dark yellowish brown, semiglossy, very astringent; veining inconspicuous; flesh crisp, rather dry; flavor sweet, mild; quality fair. *Origin:* Chance seedling in Springdale Orchards, Lakeside, Wash., 1899; specimens grown by D. H. Hulseman, crop of 1910 (Pl. V).

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[1] Bulletin 203, California Agricultural Experiment Station.

This variety is a promising one for planting in districts where climate renders the cultivation of the Persian walnut doubtful. It ought also to be of value for breeding in the Eastern States.

Chicoette.

Mayette type. Attention was first called to this variety by Mr. F. G. Peterson, head gardener at the Bidwell ranch at Chico, Cal., 1910. The tree was purchased among others and planted on the estate some years ago. E. M. Price writes of it as follows: "It is a prolific bearer; blossoms about the first of June and ripens its fruit in the early fall. It is a choice white-meated, well-flavored nut, resembling Mayette in form, and I am inclined to class it as a sport of the same."

Should this nut prove to be all that is described and be white meated under the extreme heat that frequently prevails in the region of Chico, it will be a valuable acquisition.

Cluster.

Type: Above medium to large; broadly oblong to oblong ovate; base rounded to obtuse; apex acute to acuminate, mucronate tipped; sutures appressed; flange narrow, very firmly sealed; shell bright yellow, generally smooth, though covered with a network of fine depressed veins, moderately thick, longitudinal lines well defined though not conspicuous; diaphragm strongly shouldered and quite persistent, though only of moderate thickness. *Origin:* Belgium; introduced into the United States by Felix Gillet; specimens grown upon a grafted tree by Mr. Gillet, crop of 1891 (Pl. VIII).

Mr. Gillet says, "The fruits of this variety are of average size and grow in clusters of 8 to 15." The distinctive form and general surface character of this nut are attractive. If upon further examination the quality should prove to rate high, it would be entitled to extended tests in the north Pacific coast region and in the more favorable sections of the Eastern States.

Columbus.

Mayette type. Originated with Felix Gillet from the nut of a second-generation Mayette. The nut is very large, exceedingly pretty, roundish, with smooth, light-colored shell, and kernel of first quality. Named "Columbus," in honor of the World's Fair at Chicago, 1893.[1]

Common.

Synonym of Mission and of Fertile.

Concord.

Cluster type; above medium; oblong to roundish oblong; base rounded; apex rounded to obtuse, mucronate tipped; sutures appressed or very slightly ribbed, rarely pitted at the equator; flange moderate to narrow, firmly sealed; shell moderately thin, usually grayish brown, smooth, with few furrows and pits, longitudinal lines generally indistinct; diaphragm weakly shouldered but strong and occasionally persistent; kernel full, convolutions regular, even, moderate; pellicle of a brownish cast, rather glossy, mildly astringent, veins inconspicuous; flesh crisp, slightly oily, rich; flavor sweet; quality fair to good. *Origin:* Chance seedling from an importation of Cluster nuts by Felix Gillet; first grown by J. M. Westcott, of Concord, Cal.; specimens grown by Ely I. Hutchinson, crop of 1910 (Pl. V).

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[1] Lelong, B. M. California Walnut Industry. 1895–96.

A variety worthy of extended trial. The tree is a strong, robust grower, possessed of ample, large, smooth, light-green leaves. It yields under good care a crop somewhat above the average in quantity. The nut is of attractive form and size, though the color is a trifle gray for the connoisseur. It should be an excellent parent for breeding blight-immune and late frost-proof varieties. It is recommended for trial by the University of California as blight resistant.[1]

Cosine.

A variety of no special merit, but of some historic interest as being the first Chilean seedling produced in Oregon.

Cumberland.

Parisienne type; medium to slightly above; roundish ovate; base obtuse to slightly rounded; apex obtuse to acute with mucronate point; sutures lightly ribbed or even somewhat appressed toward the base, pitted at the equator; flange narrow, firmly sealed; shell thin, but roughened with numerous irregular and variable depressions, central longitudinal lines usually well defined; diaphragm weak shouldered, thin, and rarely persistent; kernel full, plump, convolutions large, irregular, and variable; pellicle brownish yellow, dull, astringent; veins inconspicuous; flesh oily, rather rich; flavor sweet; quality fair. *Origin*: A nut brought from Germany in 1868 and planted in Carlisle, Pa., by Mrs. John Meek, produced the parent tree of this variety; specimens supplied by Miss Sarah E. Motts, crop of 1910 (Pls. VI and XI).

A variety that merits general trial throughout the walnut-growing areas of the Eastern States. It is distinctly in advance of the average seedling Persian walnut of this region.

Cutleaf.

Fertile type as to form; small, oblong to narrowly oblong; base rounded; apex obtuse to acute with mucronate tip or quite strong point; sutures slightly ribbed, pitted at the equator; flange broad, very firmly sealed; shell rather thick, smooth to slightly roughened by various furrows and occasional depressions, longitudinal lines distinct; diaphragm strongly shouldered and somewhat persistent; kernel full, plump; convolutions variable, though usually pronounced. *Origin:* Europe; specimens grown by the California Nursery Co., crop of 1891 (Pl. VIII).

This is a variety for the amateur, but of no promise for commerce. It is thus described by Felix Gillet;[2] "The foliage of this variety is so delicate, so finely cut up, that it makes a most graceful ornamental tree, worthy to be planted conspicuously in the garden or front yard. The nut, besides, is exceedingly pretty, of fair size, round, with a very smooth shell and sweet kernel. The tree is claimed to be an abundant bearer."

Dean.

Sorrento type, modified; medium to above medium; oblong to broadly oblong and not infrequently more or less obovate; base obtuse to more or less acute; apex obtuse, or even retuse to occasionally acute, with mucronate tip or sometimes a quite strong point; sutures usually appressed, though occasionally moderately ribbed; equatorial pits usually present; flange moderately broad, firmly sealed; shell rather thick, quite smooth, even and usually regular, grayish brown, splotched; diaphragm rather weakly shouldered, but inclined to toughness and usually persistent; kernel full, plump, with even, regular, moderate convolutions; pellicle dark, rich, golden brown, dull, scarcely astringent; flesh very oily, only moderately sweet; flavor mild or indifferent; quality fair. *Origin:* The parent tree of this variety was produced from a nut purchased by O. Z. Dean from the local grocery store at Shellman, Ga., in 1878 or 1879, and planted where the tree now stands. The bole is 10 to 12 inches in diameter, the foliage heavy, and the tree has been bearing 15 or 20 years. Z. P. Dean states that the crop varies from 25 to 75 pounds; specimen by courtesy of Z. P. Dean, crop of 1911 (Pl. X).

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[1] Bulletin 203, California Agricultural Experiment Station.

[2] Lelong, B. M. California Walnut Industry. 1895–96.

Derby.

Lalande type modified; medium; oblong to broadly oblong, or sometimes even slightly obovate; base obtuse to occasionally almost acutely rounded; apex almost truncate to obtuse with short, strong point usually double-tipped; sutures appressed over lower half, moderately ribbed over upper half, irregularly pitted toward or above the equator; flange very broad and firmly sealed; shell thick, strong, grayish, moderately smooth, though strongly marked with veinings, longitudinal lines pronounced, not infrequently all six fully defined; diaphragm heavy shouldered, strong, and persistent; kernel full but not plump; convolutions moderate and variable; pellicle beautiful, rich, brownish yellow, dull, slightly astringent, veins scarcely noticeable; flesh crisp, fine grain, oily; flavor indifferent, moderately sweet; quality fair. *Origin:* A seedling with S. H. Derby, Woodside, Del.; specimens from Mr. Derby, crop of 1911 (Pl. IX).

Drew.

Chaberte type; small; rounded to more or less obovate; base rounded with projecting tip of extended sutures; apex obtuse to retuse-truncate, with mucronate tip; sutures moderately ribbed, usually somewhat pitted at the equator and toward the base; flange rather broad, very firmly sealed; shell rather thin, yellowish, somewhat roughened by numerous slight depressions, pits, and protuberances; longitudinal lines usually present and well defined; diaphragm thick, heavy, firmly shouldered, and persistent; kernel full with ample and variable convolutions; pellicle dull to semiglossy, light brown, scarcely or slightly astringent; veins inconspicuous or occasionally a few dark ones; flesh rather crisp, oily; flavor rather sweet; quality fair. *Origin:* Chance seedling from a nut planted by Andrew Corsa, Milford, Del., in 1875; specimens grown by W. P. Corsa, crop of 1894.

J. L. Budd, in the American Horticultural Manual, part 2, 1903, states that the kernel of this variety is thick, plump, and easily extracted, the meat yellowish, and the quality very good. It was disseminated to a small extent, particularly in Pennsylvania. The original tree was a shy bearer and after producing a few crops was cut down. Efforts to obtain data in Pennsylvania have failed to yield any definite information.

Dwarf Prolific.

Synonym of Fertile.

Ellwood.

Nave type; medium to above medium; narrowly oblong to elliptical; base obtuse to acute; apex acute, though sometimes obtuse, with strong point; sutures moderately ribbed, pits variable, usually clustered toward the base; flange usually medium, though variable, well sealed; shell thin, bright yellow, moderately smooth, amply veined; longitudinal lines variable though usually present; diaphragm weakly shouldered, thin, and rarely persistent; kernel quite full though not plump, convolutions medium, variable, and broken; pellicle golden yellow to brownish, very mildly astringent, veins few, somewhat darker; flesh firm, crisp; flavor nutty, moderately sweet; quality fair. *Origin:* Chance seedling at the home of Ellwood Cooper, near Santa Barbara, Cal.; specimens from Mr. Cooper, crop of 1911 (Pl. XI).

Mr. Cooper looks with favor upon this type of nut, but the writer is of opinion that the elongated, elliptical, pecan-shaped walnut is not the best form for a permanent type of dessert nut.

Eureka.

Persian Long type; large, somewhat angular, rather narrowly oblong, lower half frequently tapering to base; base rounded or somewhat angular, acute, though occasionally somewhat obtuse; apex obtuse or acute, usually strongly pointed; sutures only moderately ribbed, rarely pitted at the equator; flange moderate or rather broad, very firmly sealed; shell rather thick, grayish (possibly due to bleaching), slightly roughened by irregular shallow depressions; longitudinal lines usually present and well defined; diaphragm rather firmly shouldered, thin, yielding, rarely persistent; kernel full, plump, convolutions moderate, variable, and broken; pellicle light yellow, glossy, astringent, veins usually inconspicuous; flesh rather coarse, rich, oily; flavor insipid; quality fair. *Origin:* A seedling on the Stone property, Fullerton, Cal., from a nut taken from the original Kaghazi trees on the Meak property at Haywards; first propagated by grafting in 1905; specimens grown by E. G. Ware, crop of 1910 (Pl. VII).

This variety is one of half a dozen recommended by the University of California for trial in the search for blight-immune varieties.[1] While not of high quality it may serve as parent to a variety of much greater merit if sufficiently blight resistant. The form of the nut is against it, at least for dessert purposes. Long, narrow, angular walnuts are not accepted upon the leading markets as desirable forms. The accredited form is the Grenoble, Mayette, or Parisienne, though the best grades of the Chinese would probably be equally acceptable. At the present time there is little discrimination by buyers against nuts on account of form, but as soon as the crop is produced to such an extent that markets are sought, form will become an important factor in determining the price. The Eureka is highly recommended by some leading growers of southern California as a very desirable variety, and promises to be one of the leaders in commercial plantings.

Specimens of this variety grown by Dr. W. W. Fitzgerald, of Stockton, Cal., crop of 1911, rate considerably higher in quality than those examined and described in 1910. Of the latter it may be said that the flavor is mild and sweet and the quality good, while all other essential features answer the description.

Favorite.

Approaching Franquette type; above medium to large; usually oblong though frequently unilateral, while smaller ones are sometimes rounded; base obtuse, rounded, and frequently oblique; apex obtuse with short and rather stout mucronate tip; sutures usually quite strongly ribbed, equatorial pits negligible, though pits are generally present along the surface, especially along the lower half; flange very broad and very firmly sealed;

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[1] Bulletin 203, California Agricultural Experiment Station.

shell dark grayish brown, thick, roughened with various depressions and protuberances; longitudinal lines occasionally well defined though usually broken, irregular, and negligible; diaphragm strongly shouldered, heavy, and persistent; kernel full, plump, moderate though variable convolutions; pellicle light to velvety brown, glossy to semiglossy, scarcely astringent, veins ample and dark; flesh crisp, moderately oily, and rather starchy; flavor mild; quality only fair. *Origin:* Sport of Serotina; seedling grown by Thomas R. Smith, Westport, Cal.; specimens supplied by E. M. Price, crop of 1910.

Speaking of this variety, Mr. Price says: "It blossoms early even for this altitude, 3,000 feet. It is an alternate bearer; that is, yields a full crop one year and a sparse one the next. It is immune to blight and sun scald."

Fertile.

Type, medium; rather narrowly oblong, more or less tapering to the rounded base; apex obtuse, mucronate tipped; sutures slightly ribbed, scarcely pitted at the equator; flange variable, narrow and moderately firmly sealed; shell thick, strong, grayish brown, rather smooth; longitudinal lines not infrequent and quite well defined; diaphragm quite firmly shouldered but yielding and usually not persistent; kernel full, plump, convolutions very moderate and variable; pellicle light yellowish, generally dull, though occasionally partially glossy, astringent, veins inconspicuous; flesh only moderately oily; flavor mild; quality fair. *Origin:* France, about 1838; specimens grown by Ely I. Hutchinson, crop of 1910 (Pls. VI and X).

Fertile (cluster type).[1]

A variety of Fertile said to be very fine. Originated by Felix Gillet. Nut large, oblong, smooth surface, perfect soft-shell; kernel fine and sweet. Produced in clusters.

Fertile (first generation).[1]

Introduced into California by Felix Gillet in the winter of 1870–71. The first trees of this variety to produce fruit in the State grew at Barren Hill Nurseries at an altitude of 2,600 feet. The variety originated in France in 1828 and received its name because it bore its first fruit at 2 years of age and is of surprising fertility. The nut is small, thin shelled, and very sweet. Nuts from trees of this character produce "second-generation" trees.

Fertile (second and third generation).[1]

These seedlings are of variable merit. Such title distinctions are of historical value as they call attention to the labored efforts of the past to establish and fix types and varieties by seedling propagation.

Fertile (Mayette shaped).[2]

Originated with Felix Gillet about 1870. It is a large nut sitting on its end like a Mayette, hence its name. It has a full-fleshed kernel of first quality and is a heavy bearer.

Ford.

Santa Barbara type; large, angular, broadly oblong; base obliquely obtuse to rounded; apex obtuse to acute with strong point; sutures strongly ribbed, occasionally pitted at the equator; flange usually broad, frequently imperfectly sealed; shell moderately thin, grayish, roughened by numerous slight and irregular depressions, longitudinal lines infrequent, though occasionally well defined; diaphragm moderately shouldered, thin, yielding, rarely persistent; kernel moderately full, rather plump, convolutions moderate, very variable; pellicle rather dark, generally dull, slightly astringent; flesh rather dry, starchy; flavor mildly sweet; quality fair. *Origin:* Grown by G. W. Ford, Santa Ana, Cal., from nuts procured in San Francisco, planted in the spring of 1880; specimens grown by Mr. Ford; crop of 1910 (Pl. VII).

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[1] Thus described by Lelong in his treatise entitled "California Walnut Industry," under the varietal name "Prœparturiens" [Præparturiens].

[2] Thus described by Lelong in "California Walnut Industry."

Ford's Eureka.

A name applied by Mr. Ford to seedlings of the second generation of the variety Ford, which have been distributed as seedlings. It is quite likely that this variety will disappear, yielding the name Eureka to the variety described under that name.

Ford's Improved Softshell.

Synonym of Ford.

Ford's Mammoth.

Reported by name only by H. M. Williamson in report of the Oregon Board of Horticulture, 1906.

Franmay.[1]

Franquette type; large; oblong ovate; base obtuse, ridged or spurred; apex acute, strongly pointed; sutures strongly ribbed over upper two-thirds, elevated and flattened toward the base, large open pits at the equator; flange broad, well sealed; shell rich yellow, rather thin, moderately roughened with deep lines, irregular depressions, and usually slight and variable protuberances, longitudinal lines well defined, and frequently deep; diaphragm weakly shouldered though rather strong and inclined to be persistent; kernel full, irregular, convolutions pronounced and variable; pellicle with yellowish brown tinge, glossy, astringent, veins inconspicuous; flesh rather crisp, starchy, moderately oily; flavor moderately sweet, mild; quality good. *Origin:* Grown from a nut produced by cross-fertilization between Franquette and Mayette, by Tribble Bros., Elk Grove, Cal., crop of 1911 (Pl. XI).

Franquette.

Type Vrooman; large; oblong, with tapered upper half, though in section on plane of valves, ovate; base rounded; apex acute, strongly pointed; sutures strongly ribbed, pitted at the equator; flange narrow, firmly sealed; shell thin, yellowish, frequently with reddish tinge, moderately smooth though roughened along the sutures, longitudinal lines usually present and definite; diaphragm weak shouldered, thin and rarely persistent; kernel full, moderately plump, convolutions pronounced, irregular; pellicle rich, light yellow, usually glossy, moderately astringent, veins well defined; flesh starchy, oily, rich; flavor slightly sweet, mild; quality very good. *Origin:* France; specimens grown by Vrooman estate, crop of 1910 (Pl. V).

This variety and type are highly recommended and have been extensively planted on the north Pacific coast in recent years, not only as grafted trees but as seedlings. The reasons advanced for the use of seedlings were as follows: (1) There were not enough grafted trees to supply the demand; (2) the nuts offered for sale for planting being grown in a large orchard of grafted trees of this variety alone (except for a few Chaberte trees that were grown in one corner of the orchard tract), it was held that a very large percentage of the trees would produce fruit true to name; (3) in order to plant an orchard of grafted trees one must defer the planting of any considerable acreage for an indefinite time, as this method of propagation is difficult and yields only a small percentage of marketable trees each year; (4) to incur the increased cost of grafted trees over that of nuts and seedling trees was not advisable under the circumstances; (5) the small loss occasioned by planting some seedling trees of indifferent value would be counterbalanced by the difference in cost and the increased value of the property due to immediate planting, which could be done with either nuts or seedling trees, as there were plenty of these upon the market. Whether results will confirm these views remains to be seen with the fruiting of the tracts. The eagerness of planters to set out walnuts at that time was no doubt instrumental in causing one or two points of moment to be overlooked, namely, that grafted trees usually fruit earlier than seedlings, and that the stock is an important factor which is entirely ignored in the planting of seedlings. At the same time insufficient weight is accorded the fact that seedling trees yield at best a variable product which is not true to name. With whatever variety or section concerned, the day of making a walnut orchard with nuts or seedling trees is past. Hereafter, not alone type or variety but stock and scion as well must be given full consideration, and this necessarily implies grafted or budded trees.

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[1] Tentative name, subject to the approval of the originator.

While the form of Franquette is not as acceptable to connoisseurs as that of Mayette, the uniform size, rich golden-yellow color, and peculiar rustic appearance, together with the mild-flavored fat kernel, will do much to make it a popular variety. Especially does this statement apply to the Oregon-grown Franquette, which is generally conceded to be somewhat sweeter than other American-grown specimens of this variety. The one serious fault of the Franquette is that the trees yield to the attack of the blight in several districts, though it is recommended for trial by the University of California.[1]

Garden Grove Prolific.

Synonym of Prolific.

Geit.

Parisienne type; above medium to large; roundish oblong; base obtuse to obliquely truncate; apex rounded with mucronate tip; sutures appressed over lower half, slightly to moderately ribbed over upper half, usually one or two pronounced pits at the equator; flange broad, very firmly sealed; shell thick, hard, moderately to quite smooth, longitudinal lines rarely defined; diaphragm strongly shouldered and persistent; kernel quite full, convolutions variable, broken, uneven; pellicle dark brown, astringent, semiglossy, veins inconspicuous; flesh rather crisp, rich, oily; flavor indifferent; quality fair. *Origin:* A seedling tree in Lancaster County, Pa.; first brought to public attention at the Northern Nut Growers' Convention, Ithaca, N. Y., December, 1911, by J. G. Rush.

For planting in the eastern United States this variety is not comparable with Cumberland, Holden, Mount, Nebo, Pomeroy, or Rush.

Glady.

Bijou type; very large; oblong, angular, sometimes tapering to the base; base rounded though occasionally truncate; apex obtuse or slightly acute with mucronate tip; sutures appressed, more or less depressed toward the base; flange usually narrow and firmly sealed; shell moderately thick, brownish yellow, very rough, and strongly marked with veins; diaphragm rather thick, though not strongly shouldered, usually persistent; kernel not full, somewhat shriveled, convolutions moderate and rather regular;

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[1] Bulletin 203, California Agricultural Experiment Station.

pellicle light, glossy, very astringent; veins dark and conspicuous, though not numerous; flesh dry, tough; flavor mild, moderately sweet; quality fair. Specimens grown by Ferd Groner; crop of 1910 (Pl. XI).

Grand Noblesse.

Round Mayette type; above medium to large; roundish oblong to somewhat obovate; base obtuse truncate; apex obtuse with mucronate tip; sutures appressed to slightly ribbed; pits at the equator present and pronounced or absent; flange varying from moderate to broad and quite firmly sealed; shell rather thin, usually smooth, yellowish, longitudinal lines generally present and quite well defined. *Origin:* California; reported by L. L. Bequette, of Rivera, Cal., but practically unknown in that section, as it proved of little value; crop of 1890.

Grenoble.

A term loosely used to designate the French-grown Mayette or to include the three leading varieties in the Grenoble district of France, viz, Mayette, Franquette, Parisienne. The nut shown in Plate IV, called Grenoble by the growers, T. B. Bishop Co., is really a form of Santa Barbara and not one of the three varieties here named.

Hales.

Persian Long type, modified; above medium to large; rather narrowly oblong; base obtuse to almost truncate, some specimens will stand obliquely on end; apex obtuse, usually more or less retuse, resulting from prominent shoulders, strong mucronate tip; sutures strongly ribbed, with deep, broad, and variable pits at the equator; flange very broad, strongly sealed; shell thin, moderately yellowish, fairly smooth except along sutures, amply veined and somewhat marked by small, deep pits, longitudinal lines very much broken, though not infrequently well defined but shallow and narrow; diaphragm weak shouldered, thin, and rarely persistent; kernel of shrunken appearence though filling the shell, convolutions strongly pronounced and variable; pellicle brownish, very slightly astringent; veins ample, well defined, and darker brown; flesh firm, crisp, only moderately oily; flavor very sweet, mild, pleasant; quality very good. *Origin:* Original tree grew on the property of W. L. Hale, Fullerton, Cal; specimens grown by J. B. Neff; crop of 1911 (Pl. IX).

Though this variety has not been given general trial, a few leading growers are testing it, and the following report is by J. B. Neff: "It is showing fairly well in blight-resistant qualities—in fact, better than any other variety that I have—but while the nuts are large and fine, it does not produce as large crops as some others."

Hall.

Bijou type; very large; oblong angular, usually tapering to the base; base rounded with the sutures but obtuse at right angles; apex obtuse to slightly acute, with rather strong blunt point; sutures appressed or very slightly ribbed, deeply and broadly pitted at the equator; flange broad, very firmly sealed; shell rather thick, brown with broad patches of yellowish graybrown, very rough with irregular convolutions, pits and depressions, longitudinal lines rarely marked; diaphragm firmly shouldered and usually persistent; kernel shrunken, convolutions very variable and broken; pellicle yellowish, astringent, veining inconspicuous; flesh firm, rather dry; flavor mild; quality fair. *Origin:* Chance seedling in Germany transplanted at the age of 1 year to a place near Avonia, Pa.; specimens supplied by L. C. Hall, crop of 1910 (Pl. III).

Hays.

Brantome type; medium; oblong, inclined to angularity; base obtuse to truncate, nearly half will stand erect; apex obtuse, occasionally retuse or acute, scarcely mucronate; sutures appressed toward the base, moderately ribbed at center and toward apex, pits at the equator variable; flange narrow to medium, fairly well sealed; shell thin, yellowish brown to brownish, roughened with irregular depressions and protuberances, longitudinal lines rarely defined; diaphragm strongly shouldered and inclined to be persistent; kernel quite full, moderately plump, convolutions moderate, variable, and broken; pellicle yellowish brown, glossy, astringent, veins few, darker brown; flesh crisp, grain fine, oily; flavor and quality not determinable, through age of specimens. *Origin:* A seedling on the property of Amos H. Hays, Parkton, Md., and named by H. E. Van Deman about 1904; specimens grown by Mr. Hays, crop of 1908 (Pl. IX).

Hightstown.[1]

Medium, long, ovate; shell fairly thin; kernel plump and good. A variety grown and propagated at Hightstown, N. J.; hardy and fruitful when planted in groups, as, like the chestnut, isolated trees rarely bear nuts.

Hindes Perfection.

Synonym of Placentia.

Hindes Perfection Placentia.

Synonym of Placentia.

Hindes Placentia.

Synonym of Placentia.

Holden.

Marbot type; above medium; oblong to narrowly oblong; base rounded, occasionally obtuse; apex rounded or obtuse, mucronate sutures moderately to strongly ribbed, scarcely pitted at the equator; flange broad, firmly sealed; shell grayish yellow to light yellow, moderately smooth, scattered shallow depressions, longitudinal lines usually inconspicuous; diaphragm strong and firmly shouldered; kernel quite full, convolutions moderate; pellicle light ground with darker tinge, semiglossy, astringent, veining indifferent but dark; flesh oily, rich; flavor sweet; quality good. *Origin:* Chance seedling on the property of E. B. Holden, Hilton, N. Y.; specimens grown by Mr. Holden, crop of 1910 (Pl. VII).

Honeydew.

Mayette type; large, oblong; loose, obliquely obtuse; apex obtuse with strong point; sutures rather strongly ribbed at the equator, but appressed toward the base, where abrupt enlargements along the sutures characterize the form of the nut; usually strongly pitted at the equator; shell rich yellow, rather rough from irregular basal protuberances and deep irregular depressions along pronounced sutures and longitudinal lines. *Origin:* Obtained by F. A. Leib from scions imported from France; a decided improvement in appearance over the usual Mayette obtained in a similar manner; specimen grown by Mr. Leib as first crop, 1910 (Pl. III).

Hubbard.

Sorrento type; above medium; oblong; base rounded; apex acute, with rather strong point; sutures slightly ribbed at the equator, appressed at both ends, especially at the base, usually pitted at the equator; flange very firmly sealed; shell grayish brown, quite smooth, though longitudinal lines are more or less well defined. *Origin:* California; specimens supplied by E. M. Price, crop of 1910 (Pl. VIII).

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[1] J. L. Budd, in the American Horticultural Manual, pt. 2, 1903.

To the planter who fancies this type of nut, by some called pecan-walnut and known in the market as the Italian walnut, the Hubbard promises to fulfill the demand for appearance. It is to be propagated by budding, and data to determine its value will soon be available.

Ignotum.

A name applied to a variety obtained from crossing *Juglans regia* with *Juglans cinerea*. Both tree and nut of botanical interest only.

Jauge.

Synonym of Mammoth.

Journeay.

Santa Barbara type; large; broadly oblong, or occasionally obovate and angular; base obtuse, or even obliquely truncate; apex obtuse, with strong point; sutures strongly ribbed, usually pitted at the equator; flange very firmly sealed; shell grayish yellow, roughened by numerous and often deep pits and irregular depressions; longitudinal lines rarely evident. *Origin:* Chance seedling from a Chilean nut planted in California; specimens supplied by E. M. Price, crop of 1910 (Pl. VIII).

Juglans monoheterophylla.

Synonym of *Juglans regia monophylla*. On the grounds of the Department of Agriculture at Washington is a tree of this very interesting variety marked under the synonym. As the specific name implies, the leaves are simple and variable. Those at the base of the shoots are usually broadly ovate with cordate bases, while those above vary from broadly oblong-lanceolate to narrowly lanceolate. The original tree, long since destroyed, was first observed as a chance seedling at St. Foy, near Dieppe, France, in 1833. In 1865 Carrière records (Revue Horticole, p. 130) that only two trees directly produced from the original were then in existence. The tree in Washington is small, with numerous slender branches, and is chiefly interesting on account of its remarkable foliage. The fruit is said to be of indifferent quality. Of botanical interest only.

Juglans racemosa.

Synonym of Cluster. Of this species the late Felix Gillet said: "It is a fact that the nuts are borne in clusters; aside from this character, the tree, foliage, and fruit resemble, or are even identical with, *Juglans regia*."

Juglans regia laciniata.

Synonym of Cutleaf.

Juglans regia pendula.

A specimen tree on the grounds of the United States Department of Agriculture is of moderate vigor, hardy, sprawling, somewhat pendulous, with leaves of medium size. The writer has had no opportunity to examine the fruit. A few nuts set in 1911 were probably taken before maturity by squirrels. If this authentic specimen of *Juglans regia pendula* is a fair sample, hundreds of the younger trees in California, notably in the Vrooman orchard, afford a far greater display of long, slender, pendulous branches. These are pruned each year, so that there are no examples of the kind of tree such growths would ultimately produce.

Kaghazi.

Persian Long type; above medium to large; oblong, occasionally roundish and angular, lower half usually narrowed; base rounded; apex acute or obtuse on the rounded specimens, usually with strong point; sutures moderately ribbed, more or less pitted at the equator; flange variable, firmly sealed; shell grayish brown to yellowish, rather rough, with irregular depressions, longitudinal lines more or less distinct as pitted furrows; diaphragm firmly shouldered, strong and frequently persistent; kernel full, convolutions small, irregular, and separate; pellicle light brown, glossy, astringent; veining distinct though sparse; flesh rather coarse, oily, rich; flavor sweet; quality good. *Origin:* Nuts obtained through the American consul in Persia were planted by Mr. Meak, of Haywards, Cal., and from these were produced two trees, the nuts of which were deemed especially meritorious. To these trees was given the name Kaghazi. The nuts of both trees have been used for propagation, and in consequence more or less variation exists in the type of nut, but probably no more than would be the case from any seedling trees. Specimens grown by A. L. Linquist, crop of 1910 (Pl. VI).

The trees of this variety grown near Goleta, Cal., have not been attacked by blight and are considered by Mr. Linquist and others to be blight resistant, if not altogether immune. The test will not be complete until blight has attacked in this same orchard other varieties susceptible elsewhere. Should the Kaghazi then remain free from injury, its resistance will be beyond question.

Keesling.

Persian Long type, modified; above medium to large; elliptic usually, though not infrequently oblong or occasionally almost obovate; base obtuse or rounded; apex obtuse, rounded, or even acute and usually with a strongly mucronate tip; sutures appressed to slightly ribbed, equatorial pits not pronounced and often not present; flange broad, fairly well sealed; shell rather thick, yellow, but frequently with an indifferent grayish overcast, quite regular, rather smooth, though an occasional nut is rough, with deep pits, broken lines, and furrows, longitudinal lines usually distinct; diaphragm weakly shouldered, thin, and very rarely persistent; kernel full, plump, convolutions moderate, irregular, and variable; pellicle dull to semiglossy pale brownish, quite astringent; veins few, inconspicuous; flesh crisp, oily; flavor mildly nutty; quality fair to good. *Origin:* A seedling on the property of Horace G. Keesling, San Jose, Cal., from nuts planted in 1879; specimens from grafted trees on Mr. Keesling's property, crop of 1911 (Pl. IX).

The tree is reputed to be prolific and regular. On the whole the variety appears to be worthy of trial. We are not informed as to its resistance to blight.

Klondike.

Bijou type; very large; oblong to obovate; base rounded or even long tapered; apex rounded to obtuse, mucronate; sutures appressed, usually pitted at the equator; flange narrow, many nuts imperfectly sealed; shell thick, grayish brown to yellowish brown, rough, with numerous irregular depressions and broken furrows, or quite smooth; longitudinal lines more or less distinct; diaphragm weak shouldered, though strong and frequently persistent; kernel not full, convolutions irregular, uneven, and moderate; pellicle brown tinged, mildly astringent, dull; veining generally distinct and dark; flesh coarse, rather dry; flavor sweet; quality fair. *Origin:* During the decade 1880–1890 Mr. T. L. Gooch, of Rivera, Cal., obtained specimens of nuts imported by a San Francisco firm, and from these planted by Mr. Gooch and a neighbor, Jacob Ott, to whom he had given a few, were produced two trees yielding nuts of large size and unusual shape, named Klondike by the attendants at the local packing house; specimens grown by A. L. Linquist, crop of 1910 (Pl. III).

Laciniated.

Synonym of Cutleaf.

Lane.

Santa Barbara type; above medium to large; roundish to broadly oblong; base obtuse to almost acute; apex usually acute with strong point, though sometimes rounded; sutures moderately ribbed nearly the whole length on one side while appressed near the base on the other, equatorial pits variable, sometimes wholly absent; flange usually narrow, scarcely medium, rather weakly sealed; shell thin, occasionally very thin, yellowish, smooth; well-defined longitudinal lines infrequent; diaphragm weakly shouldered, scarcely persistent; kernel full, plump, convolutions moderate, fairly regular; pellicle yellowish tinged with brown, dull, mildly astringent; veins inconspicuous; flesh crisp, medium grain, oily; flavor mild, sweet, pleasant; quality good. *Origin:* Seedling originating in Santa Barbara County, Cal., on the ranch of W. H. Johnson; specimens from grafted trees on the property of Miles P. Lane, crop of 1911 (Pl. IX).

C. W. Beers, horticultural commissioner for Santa Barbara County, Cal., says "the Lane tree produces a large, smooth nut of good quality. The tree is vigorous, assumes a desirable form, and bears an abundance of fruit spurs, even to the main body. The nuts mature so nearly at the same time that the whole crop can be successfully harvested at one picking. In 1910 and 1911 the pickings were made before the last gathering of the regular Santa Barbara in the same orchard. Growing amidst trees that lost 80 per cent of their crop by blight in 1910, this tree has shown no effects of the disease, though other trees in the same orchard have been affected. The parent tree also thus far has been exempt from this trouble."

Lanfray.

Type; large-fruited variety catalogued by Felix Gillet, but not yet reported as fruiting in the United States. H. M. Williamson, Report of Oregon Board of Horticulture, 1906, says, "It is a nut of most attractive appearance and is very heavy in proportion to size, as it is so well filled with meat."

Large Fruited.

Synonym of Bijou.

Large-Pointed Præparturiens.

Ascribed to Felix Gillet in Bulletin 92, Oregon Agricultural Experiment Station.

Late.

Synonym of Serotina.

Late Fertile.

Fertile type, small; broadly oblong to obovate; base rounded, obtuse, or occasionally truncate; apex obtuse, mucronate; sutures, strongly ribbed; broad pits at the equator usually present; flange narrow, very firmly sealed; shell yellowish, somewhat roughened, rather thick, longitudinal lines not conspicuous though generally present. *Origin:* Chance seedling at Barren Hill Nurseries; specimen grown by Felix Gillet; second generation, crop of 1891 (Pl. VIII).

Mr. Gillet said of this variety: "It is late in vegetating and hence hardy; kernel is full fleshed and very sweet."

Late Præparturiens.

Synonym of Late Fertile.

Lea.

Montignac type; medium to small; roundish, angular, occasionally tapered toward apex; base obtuse truncate, many specimens will stand erect; apex obtusely rounded, scarcely any tip; sutures slightly to broadly ribbed over upper half, appressed below; variously pitted at the equator, pits usually indifferent; flange very narrow, firmly sealed; shell very thin, grayish brown to yellowish, moderately smooth, longitudinal lines rarely well defined; diaphragm strongly shouldered, strong, and persistent; kernel full, plump, convolutions moderate, broken, variable; pellicle brownish, dull to semiglossy, very mildly astringent; veins inconspicuous; flesh crisp, starchy, moderately oily; flavor mild, sweet; quality fair. *Origin:* Wilmington, Del., about 20 years ago. It is a seedling from another tree, also a seedling, planted in the locality about 40 years ago. It began bearing at 8 or 9 years of age and has borne yearly since. Owing to the thin shell of the nut, blackbirds do considerable damage to the crop. It is in excellent repute for pickling, being superior in flavor to other varieties used for this purpose. Specimens grown by Miss Lea, Wilmington, Del., crop of 1911 (Pl. IX).

Longbeaked.

A variety catalogued by the Georgia Horticultural Society in its report for 1900. Probably a synonym for Serotina.

Los Angeles.

Synonym of Mission.

Mammoth.

Bijou type; an immense nut, the largest yet originated. So large are the shells of some that "ladies' companions," wherein to stow away gloves and handkerchiefs, are made from such shells by fancy-goods manufacturers. The nut though of such large dimensions has a thin shell and the kernel is of first quality.[1]

Mammoth Fertile.

A large-fruited variety of the Fertile that originated in France. The nut is extraordinarily large; soft shell; full-fleshed kernel.[1]

Mayette.

Type, Kerr form; large; ovate, rarely oblong; base obtuse; apex obtuse to slightly acute with mucronate tip; sutures appressed to slightly ribbed, pitted at the equator; flange narrow, very firmly sealed; shell thin, grayish yellow, quite smooth except along the sutures, longitudinal lines quite distinct; diaphragm usually weakly shouldered, thin, and rarely persistent; kernel full, only moderately plump, convolutions pronounced, somewhat irregular, pellicle grayish yellow, glossy, very slightly astringent; veins sparse, but usually well defined by their darker color; flesh oily, rich; flavor sweet; quality very good. *Origin:* France; specimens grown by Tribble Bros., crop of 1910 (Pl. V).

Mayette Blanche.

A Mayette having a light-colored or whitish flesh.

Mayette Longue, Mayette Ronde, and Mayette Rouge.

A Mayette having reddish-colored flesh.

Type forms recognized as authentic in France, but not yet distinguished by American growers or in the American market.

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[1] Lelong, B. M. California Walnut Industry. 1895–96.

Mayette Seedling.

A "second-generation" Mayette, grown by George C. Payne, Campbell, Cal., differs from the Kerr type in that the nut is more ovate, the upper half more tapering, and apex more acute; the shell is a rich yellow, the sutures not quite so firmly sealed, and the flavor better.

A type of Mayette grown by Thomas Prince, Dundee, Oreg., conforms very closely to the Payne "second generation" type in both color and form, though there is a larger percentage of oblong specimens; they have a reddish tone added to the rich yellow of the Payne Mayette; they are perceptibly smaller, though very uniform, with a kernel that is sweeter and less oily.

A seedling Mayette grown by Ely I. Hutchinson, Concord, Cal., conforms in color and form very closely to the Kerr type, though somewhat smaller, with a rather sweeter and more oily kernel.

A seedling Mayette grown by E. Terpenning, Eugene, Oreg., is medium in size, very sweet, and firmly sealed. The tree is reputed to be a regular and heavy bearer.

Mayquette.

Franquette type; above medium to large; oblong, with upper half tapered and somewhat angular; base obtuse to slightly rounded; apex acute or occasionally obtuse, with rather strong point; sutures strongly ribbed, pitted at the equator; flange broad, very firmly sealed; shell rather thick, roughened with irregular protuberances and irregular variable depressions and pits and a few deep-seated veins, longitudinal lines usually well defined; diaphragm strongly shouldered, thin but usually persistent; kernel full, plump, convolutions pronounced and broken; pellicle brownish tinged, glossy, slightly astringent; veins inconspicuous; flesh crisp, oily, starchy; flavor moderately sweet, pleasant, mild; quality fair to good. *Origin:* A seedling from artificial pollination of Franquette × Mayette by Tribble Bros., Elk Grove, Cal.; specimens from the above firm, crop of 1910 (Pls. VI and X).

Mesange.

Modified Franquette type; small, oblong to oblong ovate; base obtuse, rarely truncate; apex acute with strong point; sutures somewhat appressed toward the base, moderately to strongly ribbed above, slight pits usually present at the equator; flange narrow, very firmly sealed; shell yellowish or grayish yellow, thin, more or less roughened by slight irregular depressions; variable furrows and small protuberances; longitudinal lines commonly present and well defined. *Origin:* Europe; specimens grown by Felix Gillet; second generation, crop of 1891. Introduced by Mr. Gillet. Elicited from the importer the following comment after its first fruiting in this country: "It is so named from the fact that the shell is so thin that the titlark, though a little bird, can pierce it and thus feed upon the kernel. The tree is very productive, while the nut is excellent for dessert and pickling, and is quite rich in oil."

Meylan.

Type; above medium; ovate or broadly oblong; base truncate; apex obtuse or acute, mucronate; sutures appressed to slightly ribbed, slight depressions, rarely a small pit at the equator; flange narrow to moderate, very firmly sealed; shell thin, rich yellow, smooth and regular, longitudinal lines frequently well defined; diaphragm firmly shouldered, thin and yielding; kernel full, moderately plump, convolutions moderate, irregular; pellicle light yellowish, glossy or dull, very slightly astringent, veins sometimes abundant, giving the kernel a brownish cast; flesh very oily, rich; flavor sweet, pleasant; quality best. *Origin:* Europe; specimens grown by Ely I. Hutchinson, crop of 1910 (Pl. III).

A type of Meylan grown by Mr. Prince is somewhat smaller and darker with veins of the shell more conspicuous, kernel somewhat darker and not so plump though sweeter and less oily.

Milbank.

Parisienne type; above medium; oblong; base obliquely obtuse to obliquely truncate, about half will stand nearly erect upon base; apex obtuse, often more or less oblique, and apparently depressed as result of prominent shoulders, tip varies from practically none to an occasional rounded one of some strength; sutures with basal half appressed, apical half more or less ribbed, equatorial pits less pronounced than in the type but usually present at least on one side, occasionally quite deep depressions near the base; flange broad, usually firmly sealed though not difficult of separation; shell moderately thin, of pleasing yellowish color, moderately smooth, though well marked with shallow veining, longitudinal lines distinct though often irregular and broken; diaphragm strongly shouldered at basal end in particular and usually persistent; kernel full, convolutions rather strong and variable though moderately smooth, veins indistinct; pellicle light glossy to semi-glossy, mildly astringent; flesh tender, crisp, moderately rich; flavor mild, rather sweet and pleasant; quality good. *Origin:* A seedling planted on the property of the late Mrs. Jeriamah Milbank, in Connecticut, about 1876; specimens from the original tree, crop of 1911 (Pl. IX).

While the tree is not a heavy bearer, it produces a good average annual crop and is said to be a robust, vigorous grower.

Mission.

Type; medium; oblong or obovate and somewhat angular; base obtuse to rounded; apex obtuse with mucronate tip or strong point; sutures from slightly to strongly ribbed, indifferently pitted at the equator; flange usually broad, firmly sealed; shell grayish brown, thickened by numerous irregular protuberances and roughened by pits and depressions, longitudinal lines occasionally well defined. *Origin:* California; specimens grown by Charles S. Wilcoxon, crop of 1891.

This variety was planted by the Spanish padres about the early missions in California. It is not now of commercial importance nor of varietal consequence. It is also known as Santa Barbara Hardshell.

Mobart.

Merely listed and illustrated by Lelong in his treatise entitled "California Walnut Industry."

Mount.

Marbot type; medium; oblong, somewhat angular and occasionally tapering to the base; base rounded to acute; apex obtuse, infrequently truncate, mucronate; sutures quite strongly ribbed, sometimes pitted at the equator, but usually merely slight depressions; flange moderate, very firmly sealed; shell rather thick, bright yellow, moderately smooth, longitudinal lines usually present and well defined though sometimes variously broken; diaphragm rather thick, firmly shouldered, frequently persistent; kernel quite full, fairly plump, convolutions moderate, irregular and broken; pellicle reddish, dull, astringent; veins inconspicuous; flesh somewhat coarse, oily; flavor indifferent; quality fair. *Origin:* Original tree is growing upon the property of Joseph S. Mount, Hamilton Square, N. J.; was planted as a small tree in 1884 and has borne more or less of a crop since 1890, when it produced its first fruit; specimens grown by Mr. Mount, crop of 1909 (Pl. VIII).

Nebo.

Parisienne type; large; broadly oblong to oblong ovate; base obtusely rounded; apex retuse with very slight mucronate point; sutures strongly ribbed above but depressed below and distinctly pitted at the equator. *Origin:* Chance seedling in Lancaster County, Pa.; specimens supplied by J. G. Rush, crop of 1910 (Pl. V).

Neff.

Santa Barbara type; large; roundish oblong, occasionally tapering toward the base, quite angular and irregular; base rounded and usually with one lobe projecting; apex obtuse with strong point; sutures quite strongly ribbed, occasionally pitted at the equator; flange broad, only moderately sealed; shell rather thick, grayish yellow, roughened with numerous depressions, largely due to strong veining and slight rounded protuberances, longitudinal lines quite well defined though usually broken; diaphragm strongly shouldered but thin and yielding, scarcely persistent; kernel moderately full and plump, convolutions usually slight though variable and broken; pellicle with a decided brownish tinge, glossy, mildly astringent; veins dark and well defined; flesh rather crisp, oily; flavor sweet, mild, pleasant; quality good. *Origin:* A tree obtained from a local nursery dealing in seedling stock planted among other trees from the same nursery at the same time—1892—by J. B. Neff, Anaheim, Cal.; Mr. Neff reports it to be the most prolific and regular bearer that he has. He also says: "It is not the smooth nut that I would like." Specimens grown by Mr. Neff, crop of 1910 (Pl. V).

Neff Prolific.

Synonym of Neff.

Norman.

Synonym of Pomeroy.

Papershell.

Synonym of Mesange. The term "Papershell" is also used for a variety with a very thin shell, formerly planted in California, but discarded as wholly unfit for the commercial orchard because the tree is a shy bearer, though the nut is of high quality.

Paradox.

A name first used by Luther Burbank in 1897–98 to designate a tree from a nut produced by a cross-fertilization of *Juglans regia* and *J. californica.* The term is now used to distinguish any tree arising from the cross-fertilization of these two species (Pl. II).

Parisienne.

Type; above medium to large; oblong, upper half often tapers to such extent that it has the appearance of being ovate; base obliquely obtuse; apex usually obtuse, though occasionally rounded with mucronate tip; sutures appressed to slightly ribbed, usually deep pitted at the equator, which is often below a median line; flange narrow to moderately broad, firmly sealed; shell thin, brownish, roughened with numerous irregular and shallow pits, longitudinal lines variable, usually indistinct; diaphragm weakly shouldered, thin but strong; kernel full, convolutions moderate, regular, and rather smooth; pellicle light, glossy, mildly astringent; flesh tender, oily, rich; flavor sweet; quality very good. *Origin:* Southeastern France nearly 200 years ago. Now rated by the French as one of the three highest quality dessert nuts. Specimens grown by George C. Payne; crop of 1911 (Pl. V).

Parry.

Illustrated in American Fruit and Nut Journal, June, 1908; also in Bulletin 92, Oregon Agricultural Experiment Station, in which publication it is said to be of medium size and rather flat at the base.

Payne.

Franquette type; above medium; oblong with upper half narrowed, or even almost tapering to the apex; base obtuse to rounded; apex sometimes rounded, usually acute with a strong point; sutures strongly ribbed, only moderately or not at all pitted at the equator; flange moderate and variable, firmly sealed; shell moderately thin, yellowish, rather smooth, though usually more or less furrowed and pitted with shallow depressions; diaphragm firmly shouldered but thin and weak; kernel full, convolutions even and moderate; pellicle light to slightly tinged with brown, very slightly astringent, veining slightly dark, though not pronounced; flesh rather dry; flavor mild, hardly sweet; quality fair. *Origin:* Accidental seedling discovered at Campbell, Cal., by George C. Payne, about 1898; parentage unknown, but of Franquette type. Specimens grown by Mr. Payne; crop of 1910 (Pl. VII).

Of this nut an Oregon grower, Mr. Ferd Groner, says: "It is a fine nut, but the blight affects it seriously. It is not adapted to Oregon conditions because it blossoms too early."

Payou.

Bijou type; very large; oblong, usually somewhat angular and narrowed at the base; base rounded; apex obtuse, mucronate; sutures appressed or slightly ribbed, narrowly and deeply pitted at the equator, which usually lies above a median line; flange narrow, imperfectly sealed; shell moderately thin, yellowish brown to darker, very rough with irregular convolutions and numerous depressions, longitudinal lines frequently evidenced by a series of narrow, deep pits; diaphragm firmly shouldered but thin and weak; kernel quite full, convolutions regular and large; pellicle rather dark, glossy, slightly astringent, veining quite pronounced and dark; flesh oily, rich; flavor sweet; quality very good. *Origin:* Offspring of a cross between Bijou and Payne made by George C. Payne in 1903 or 1904; specimens grown by G. C. Payne, the originator; crop of 1910 (Pl. III).

Pear Shape.

Synonym of Vilmorin.

Peerless (Papershell).

Bijou type. Originated with Mrs. Rebecca E. Semple, Burlington, N. J., from a nut planted by her in 1893. Reported as promising for Maryland in Bulletin 125, Maryland Agricultural Experiment Station. Considering the type to which the name "Papershell" has been applied in the past, the term is a positive misnomer.

Persian.

Type; medium; roundish oblong; base obliquely obtuse to rounded; apex obtuse to acute with mucronate tip; sutures moderately to quite strongly ribbed, irregularly pitted at the equator; flange moderate, very firmly sealed; shell thin, grayish yellow, rather thick, strong, moderately rough with numerous depressions and a few protuberances, longitudinal lines indistinct; diaphragm weakly shouldered, thin, scarcely persistent; kernel full, plump, convolutions large and variable; pellicle light yellowish brown, glossy, scarcely astringent, veins not conspicuous; flesh crisp, slightly oily; flavor very sweet, mild; quality good. *Origin:* Imported from France; specimens grown by Ely I. Hutchinson; crop of 1910 (Pl. IV).

Though Persian is a generic commercial term in general use, it is used in this case by Mr. Hutchinson and some others to designate a particular type of nut of medium size that has made a record for productiveness, while at the same time possessing considerable merit as a nut of high quality. It can hardly be classed as a "soft-shell" in the strict meaning of the term.

Persian Dwarf Prolific.

Synonym of Fertile.

Persian (round).

Nuts of the crop of 1911 were imported by the Office of Foreign Seed and Plant Introduction, Bureau of Plant Industry.

Placentia.

Santa Barbara type; large, decidedly angular; obovate to oblong; base rounded; apex obtuse to rounded, mucronate; sutures decidedly appressed, small, deep pits, few to none at the equator; flange narrow, firmly sealed, though a considerable number of specimens are imperfectly closed at apex; shell thin, dark brown, mottled with gray, rough with numerous pits of various sizes and broken ribs, longitudinal lines negligible; diaphragm variable, though usually more or less persistent; kernel full size though not plump, convolutions variable and irregular; pellicle light yellowish brown, more or less glossy, slightly astringent, veins few but sometimes quite pronounced by their dark color; flesh moderately oily; flavor sweet; quality good. *Origin:* Chance seedling about 1890 in Orange County, Cal.; specimens grown by J. B. Neff; crop of 1910 (Pls. VI and XI).

Placentia Perfection.

Synonym of Placentia.

Pomeroy.

Small; oblong; base rounded; apex rounded, occasionally slightly pointed, usually mucronate; sutures appressed or occasionally very slightly ribbed, scarcely pitted at the equator; flange broad, firmly sealed; shell smooth, thick, grayish brown to light yellowish, longitudinal lines inconspicuous; diaphragm strong, firmly shouldered, persistent; kernel full, convolutions moderate; pellicle light yellowish, astringent, veining generally inconspicuous; flesh moderately oily; flavor very sweet; quality good. *Origin:* With the late Norman Pomeroy, Lockport, N. Y., from nuts obtained by him from a tree in Philadelphia, and planted in 1876; specimens grown by Mr. Pomeroy, crop of 1910 (Pl. X).

Poorman.

Listed by Lelong, in "California Walnut Industry," as a variety of recent introduction.

Precocious.

Synonym of Fertile.

Prince.

Persian Long type; large; oblong to narrowly oblong, tapering to apex; base rounded; apex acute, occasionally obtuse, mucronate pointed; sutures appressed, moderately or not at all pitted at the equator; flange variable, usually narrow, not quite firmly sealed; shell dark brown, very conspicuously marked with narrow and slightly depressed veins producing the appearance of roughness while in truth it is quite smooth and even, longitudinal lines variable; diaphragm usually firmly shouldered, thin but strong and at times persistent; kernel not quite full, rather irregular, convolutions variable, generally only moderate; pellicle light yellow to brownish, glossy, mildly astringent; flesh moderately oily; flavor sweet, rich;

quality good. *Origin:* Chance seedling with the late Felix Gillet, California, about 1895; specimens grown by Mr. Prince, crop of 1910 (Pls. VII and XI).

Sold with others to fill an order for trees supplied to Thomas Prince, Dundee, Oreg. Its distinct form, size, and color so easily distinguished it from the other nuts in the orchard that it was given the above name after fruiting a few times. Unfortunately, it is not blight resistant at its home.

Prince of Yamhill.

Synonym of Prince.

Prolific.

Persian Long type; large; oblong to obovate; base rounded; apex usually acute with point obtuse or mucronate; sutures moderately or even strongly ribbed, rarely pitted at the equator; flange usually broad, firmly sealed; shell thin, grayish brown, roughened with numerous irregular and frequently rather deep pits and depressions, longitudinal lines usually present and well defined; diaphragm almost weakly shouldered, thin and yielding, rarely persistent; kernel full, plump, convolutions moderate and quite regular; pellicle rather dark (probably due to climate), glossy, astringent; flesh rather rich, very oily; flavor sweet; quality good. *Origin:* Chance seedling with E. G. Ware, Garden Grove, Cal., from a Santa Barbara nut obtained from the Sexton place; first propagated by grafting in 1899; well worth extended trial; specimens grown by Mr. Ware, crop of 1910 (Pl. VII).

Prœparturiens or Præparturiens.

Synonym of Fertile.

Rivera Hardshell and Rivera Softshell.

Listed and illustrated by Lelong in his treatise entitled "California Walnut Industry."

Royal.

A name first used by Luther Burbank in 1897–98 for a tree from a nut produced by a cross-fertilization of *Juglans californica* and *J. nigra*. The name is applied to any tree that is the offspring of cross-fertilization between these two species (Pl. II).

Rush.

Parisienne type; medium; roundish oblong to oblong, occasionally somewhat oblique; base obtuse truncate; apex very slightly rounded or even depressed; scarcely mucronate; sutures appressed or slightly ribbed, usually slightly pitted at the equator; flange broad, very firmly sealed; shell grayish brown, roughened by numerous small, shallow depressions, longitudinal lines inconspicuous; diaphragm firmly shouldered, strong and persistent; kernel full, convolutions moderate; pellicle light golden tinge, slightly astringent, glossy; veining moderate and dark; flesh medium texture, moderately oily; flavor sweet, rich; quality good. *Origin:* Chance seedling in 1886, with J. G. Rush, West Willow, Pa.; specimens grown by Mr. Rush, crop of 1910 (Pl. VII).

Santa Barbara.

Type; above medium to large; form variable, oblong or broadly oblong, the lower half frequently tapering and occasionally oblique; base rounded; apex obtuse to acute with mucronate tip or firm point; sutures medium to strongly ribbed or sometimes appressed, not infrequently pitted at the equator; flange variable, firmly sealed; shell moderately thin, grayish, or yellowish; from quite rough to moderately smooth, longitudinal lines negligible; diaphragm rather weakly shouldered, thin and scarcely persistent; kernel full, rather plump, convolutions moderate, irregular, and broken;

pellicle yellowish brown, slightly astringent, glossy, veins rather numerous, especially the smaller ones noticeable; flesh rather dry; flavor moderately sweet; quality good to very good. *Origin:* Chance seedling from nuts thought to have been imported from Chile planted in Santa Barbara County, Cal., by Joseph Sexton in 1886; specimens grown on La Patera Ranch, crop of 1910 (Pl. IV).

The type of this variety is extremely variable in minor details, a result of the practice of propagating from nuts selected to meet the ideas of the respective growers. While these ideas coincide in a general way, there are marked differences as to form, and at best growers do not confine themselves closely to definite ideals. It is easily understood that the production of uniform nuts is difficult to attain from seedlings, and so long as this method is pursued we can hardly expect to have other than a very variable type.

Santa Barbara (More form).

The favorite form of the Santa Barbara as selected by John F. More; somewhat more angular than the nut described; a more pronounced apical point; rougher; sutures more strongly ribbed. Specimens grown by Mr. More, crop of 1910 (Pl. IV).

Santa Barbara (Williams form).

An improved form of Santa Barbara selected by George M. Williams. The sutures are more appressed and the nut smoother, though in other respects conforming closely to the general type of this variety as now propagated in southern California. Specimens grown by Mr. Williams, crop of 1910 (Pl. IV).

Santa Barbara Softshell.

Synonym of Santa Barbara.

San Jose Mayette.

Synonym of Wiltz.

Santa Rosa.

Santa Barbara type; above medium to large; oblong with broadly oblong or tapering lower half; base rounded and commonly oblique; apex acute or obtuse with strong point; sutures strongly ribbed, rarely pitted at the equator; flange variable, only moderately sealed; shell thin, grayish to yellowish, roughened particularly along the sutures by irregular depressions, pits, and protuberances, longitudinal lines infrequent, occasionally well defined; diaphragm firmly shouldered, generally thin and weak, rarely persistent; kernel full, moderately plump, convolutions pronounced and variable; pellicle rich yellowish brown, glossy, astringent, veins rather sparse, but generally well defined; flesh oily, rich; flavor sweet; quality good. *Origin:* Chance seedling at San Francisco years ago, but later moved to Santa Rosa, where it now stands; first introduced by Luther Burbank in 1882–83; specimens grown by George C. Payne, crop of 1910 (Pl. IV).

Serotina.

Franquette type, modified; small; ovate, occasionally somewhat oblong; base obtuse to truncate; apex acute to acuminate, with strong point; sutures appressed at the base, moderately to strongly ribbed above, pits at the equator, narrow and deep; flange moderate, very firmly sealed; shell yellowish, smooth, rather thin, longitudinal lines usually well defined; diaphragm thick, strongly shouldered, and often more or less persistent. *Origin:* Europe; specimens grown by Felix Gillet; second generation, crop of 1891 (Pl. VIII).

In a brief description of this variety in 1887–88, Mr. Gillet said: "This variety is of especial value for planting in those districts where late spring frosts prevail, as it is very late in vegetating. The tree is very prolific and the nut is of medium size, well shaped, with a very sweet and highly flavored kernel."

Sexton.

Originated with Joseph Sexton, in California, but not a well-defined variety with individual merit, and not propagated.

Sexton's Papershell and Sexton's Softshell.

Synonyms of Santa Barbara.

Sinclair.

Parisienne type; above medium to large; broadly oblong; base obtuse truncate; apex obtuse to slightly retuse, with mucronate tip; sutures appressed at base, slightly ribbed; irregularly if at all pitted at the equator, which is above a median line; flange narrow, firmly sealed; shell medium thick, pleasing yellow, moderately smooth, though the abundant veining gives it the appearance of roughness, longitudinal lines usually present and well defined; diaphragm strongly shouldered, rather thick, and somewhat persistent; kernel full, plump, convolutions moderate and variable; pellicle dark, semiglossy, very astringent; veins ample and dark; flesh crisp, rather oily, and starchy; flavor insipid; quality fair. *Origin:* A seedling on the property of L. J. Onion, Harford County, Md.; specimens from Mr. Onion, crop of 1911 (Pl. IX).

Smith's Favorite.

Synonym of Favorite.

Stocktonian.

Franquette type, slightly modified; large; oblong to oblong ovate, or even occasionally elliptic; base obtuse or irregularly rounded; apex obtuse to acute with short, strong point; sutures rather strongly ribbed, indifferently pitted toward the base; flange broad and quite firmly sealed; shell moderately thin, bright yellow, somewhat roughened by various irregular depressions, longitudinal lines almost absent; diaphragm strongly shouldered, rather heavy and persistent; kernel only moderately full, not plump, convolutions variable, but usually pronounced; pellicle dull, light brown, astringent; veins inconspicuous; flesh starchy, oily; flavor indifferent; quality fair. *Origin:* E. M. Price says: "It is a seedling of Serotina; bears every year, and is prolific; blossoms early and has not yet been affected by blight." Specimens supplied by E. M. Price, crop of 1910.

Teague.

Santa Barbara type; medium, though rather variable in size and also form; roundish oblong to broadly oblong with decidedly tapering base in many specimens; base obliquely obtuse to rounded or even acute; apex obtuse or acute, mucronate tip to firm point; sutures moderate to strongly ribbed, rarely pitted at the equator; flange usually broad, firmly sealed, though frequent specimens are imperfectly closed; shell thin, yellowish, varying from quite smooth to roughened by numerous irregular shallow depressions and protuberances, longitudinal lines rarely noticeable; diaphragm weakly shouldered, thin, and scarcely persistent; kernel very full and plump, convolutions variable, moderate; pellicle light yellow tinged with brown, dull, semiglossy, slightly astringent, veins numerous and brown to dark brown; flesh oily; flavor moderately sweet; quality fair. *Origin:* Chance seedling of the Santa Barbara; planted in Ventura, Cal., in 1886, and reputed to be blight immune; specimens grown by Dana L. Teague, crop of 1910.

Thinshelled.

A variety catalogued by the Georgia Horticultural Society, report for 1900; possibly Hightstown, which has sometimes passed under the name of Thinshelled.

Titlark.

Synonym of Mesange.

Treyve.

Parisienne type; above medium; oblong, with an appearance of angularity; base obtuse; apex obtuse, mucronate; sutures slightly ribbed to appressed, usually strongly pitted at the equator; flange moderately broad, firmly sealed; shell brownish, mottled with gray, slightly roughened, with scattered shallow depressions and pits along the sutures, longitudinal lines depressed, generally indistinct or broken, though occasionally well defined; diaphragm strong and firmly shouldered; kernel moderately full, convolutions medium to large; pellicle very light, semiglossy, astringent, veining indistinct; flesh moderately oily; flavor moderately sweet, mild; quality good. *Origin:* France; specimens grown by Ely I. Hutchinson, crop of 1910 (Pl. VII).

Vilmorin.

A hybrid between *Juglans regia* and *J. nigra*, originating in France and introduced into the United States by Felix Gillet. "The nut has the shape of the Persian walnut, or rather that of Serotina, and the shell the appearance and hardiness of the black walnut. A very curious nut, but not desirable for market."[1]

Volga.[2]

Medium; long, ovate; shell quite thin; quality good; grown by the writer from nuts picked up at Saratov, on the Volga, in Russia. It proved hardy enough to endure winters in central Iowa, and is now propagated in Missouri.

Vourey.

Franquette type, modified; small to medium, broadly oblong ovate; base obliquely truncate; apex obtuse to acute, with firm point; sutures strongly ribbed, broadly pitted at the equator; flange narrow, firmly sealed; shell yellowish, thin, roughened by numerous irregular depressions and protuberances; diaphragm firmly shouldered, thin, though frequently persistent. *Origin:* Near Vourey, in southeastern France; specimens grown by John Rock, California Nursery Co., crop of 1891 (Pl. VIII).

Of this variety the late Felix Gillet said, "It is much the same form as Parisienne and possesses its superior quality." Of its quality the writer can not speak, since the material from which the above description was made was 9 years old, rancid, and worm-eaten; but the form, while very unlike a Parisienne, much resembles Franquette, more particularly its upper two-thirds, with a decidedly truncate base (a Mayette character), and the same strongly ribbed sutures, with an extended, firmly pointed apex. It is evident that the Rock and Gillet types of Vourey are not the same, but quite different nuts. Upon the general character of the Vourey, Berthet remarks, "This variety holds a middle place between Mayette and Franquette; it is smaller than the first and as rustic as the second." He adds that it is a dessert nut and is later than Mayette by 15 days.

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[1] Catalogue, Barren Hill Nurseries, 1887–88.

[2] J. L. Budd, American Horticultural Manual, pt. 2, 1903.

From the above statements it appears that the Rock type is approximately true to the French standard and quite possibly would serve as a parent for American stock.

Ward.

Cahor type; medium to slightly above; oblong; base rounded; apex obtuse to acute, mucronate tip; sutures appressed or very slightly ribbed, rarely pitted at the equator; flange narrow to variable, firmly sealed; shell rather thin though strong, grayish brown, moderately smooth to roughened by wavy and slightly raised convolutions and narrow depressed veins, longitudinal lines rarely present; diaphragm weakly shouldered, thin, though somewhat persistent; kernel full, plump, convolutions regular, even, and pronounced; pellicle light yellow to brownish, dull, very slightly astringent; flesh crisp, slightly oily, rich; flavor sweet; quality fair to good. *Origin:* Accidental seedling with W. H. Ward, Morgan Hill, Cal., about 1897; tree hardy, prolific, thus far free from blight; specimens grown by Mr. Ward, crop of 1910 (Pl. V).

Weaver.

Fertile type, modified; small; oblong; base rounded to obliquely obtuse; apex obtuse to slightly acute, mucronate tipped; sutures slightly ribbed to somewhat appressed, more or less pitted at the equator; flange rather broad, very firmly sealed; shell brownish gray, thick, slightly roughened by numerous small, irregular depressions and an occasional pit, longitudinal lines usually present though more or less irregularly broken; diaphragm firmly shouldered, thick and persistent; kernel full, plump, convolutions very moderate, broken, and variable; pellicle brownish yellow, dull, slightly astringent; veins inconspicuous or rarely well defined; flesh oily, starchy, rather coarse; flavor insipid, scarcely sweet; quality poor to fair. *Origin:* Chance seedling on the Weaver estate near Martinsburg, W. Va.; reputed to be approximately 75 years of age and a regular and heavy bearer; specimens from the original tree, crop of 1910.

Weeping.[1]

Probably a synonym of *Juglans regia pendula*. Felix Gillet says: "Still another new and valuable variety; it derives its name from its branches drooping under the weight of nuts, we presume, like a weeping willow." Further than this we have found no record of the variety in the United States.

Willson.

A large nut of the Bijou type originating in Santa Clara County, Cal., about 1910; said by the introducer to be very precocious, productive, and blight proof.

Willson's Acme.

Synonym of Acme.

Willson's Wonder.

Synonym of Willson.

Wiltz.

Mayette type; large, broadly oblong, sometimes narrowed at base; base slightly rounded to obtuse; apex obtuse, acute pointed; sutures slightly ribbed to appressed, usually pitted at the equator; flange narrow, occasionally imperfectly sealed; shell very thin, light yellowish, moderately smooth with depressions about the sutures, longitudinal lines depressed and well defined; diaphragm weak shouldered and thin; kernel full, convolutions pronounced; pellicle light, semiglossy, very slightly astringent; veining inconspicuous; flesh moderately oily; flavor sweet; quality very good. *Origin:* Chance seedling discovered on the Stevens Road near San Jose, Cal., about 1892; specimens grown by R. Wiltz, crop of 1910 (Pl. XI).

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[1] Catalogue, Barren Hill Nurseries, 1887–88.

This is another of the varieties recommended for trial by the University of California as promising in the work against blight.[1] The fact that one tree in the home orchard of Mr. Wiltz has grown for nine years between two trees of other varieties and while they are more or less affected with blight each year it remains free is excellent evidence that this variety promises to be blight resistant. Before positive statement can be made there must be extended trial over a wide area under variable conditions. Should it stand the test it will be widely planted, for it possesses several qualities esteemed by the dealer and consumer, being of excellent size, form, and color and of good quality and flavor. The nuts are quite uniform, with a small percentage of culls, and the tree is fairly productive, though not a robust grower. Mr. Wiltz states that the trees may be set in permanent orchard at 30 feet apart and have ample room. This is based on the growth of the tree upon its own roots. It is quite probable that the variety would make a larger growth upon the native black or hybrid stocks.

Wiltz Mayette.

Synonym of Wiltz.

WEIGHT AND MEASUREMENT.

Table II gives the weight and measurement of several hundred average specimens of Persian walnuts from the crop of 1910. The weights were made in February, 1911. The nuts had been stored so as to insure dry specimens under uniform treatment. The figures are merely approximate, as the weight of nuts varies from year to year. The variation in both the development of the kernel and in the thickness and weight of the shell depends upon climate, soil, food, and water. These figures may serve as a basis for more comprehensive work in future investigations. Allowance must be made for the personal equation in the fact that different people selected the average specimens of several varieties.

The weight gives the number of nuts to the pound; the measurements are of diameters in inches (1) at right angles to the sutures, (2) in the plane of the sutures, (3) from base to apex. The French Mayette, as sold on the New York market for 1910, is used as a leader, merely for comparative purposes.

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[1] Bulletin 203, California Agricultural Experiment Station.

TABLE II.—*Average weight and size of typical specimens of Persian walnuts, by varieties.*

[Varieties illustrated in the plates are indicated by an asterisk (*).]

Variety.	Nuts to the pound.	Diameter (in inches). (1) Across sutures.	(2) Plane of sutures.	(3) Longitudinal.
Alpine*		1.47	1.48	1.81
Barnes	45	1.26	1.25	1.43
Bijou*	24	1.58	1.58	1.80
Chaberte*	53	1.17	1.05	1.30
Chase*	30	1.47	1.44	1.80
Chelan*	50	1.18	1.17	1.53
Concord*	40	1.31	1.22	1.53
Cumberland*	41	1.25	1.22	1.33
Eureka*	33	1.20	1.18	1.80
Fertile* (Hutchinson)	48	1.15	1.13	1.47
Fertile (Prince)	54	1.13	1.08	1.40
Ford*	30	1.47	1.37	1.72
Franquette (Hutchinson)	39	1.27	1.25	1.69
Franquette* (Vrooman)	36	1.31	1.34	1.87
Glady*	30	1.63	1.45	1.87
Hales*	41	1.22	1.30	1.62
Honeydew*	34	1.44	1.30	1.75
Hubbard*	43	1.16	1.11	1.64
Journeay*	37	1.34	1.25	1.61
Keesling*	37	1.26	1.23	1.53
Hall*	26	1.55	1.44	1.67
Holden*	40	1.30	1.23	1.63
Kaghazi*	35	1.38	1.31	1.70
Klondike*	35	1.42	1.25	1.84
Mayette*	44	1.33	1.22	1.44
Mayette (French grown)	54	1.25	1.18	1.41
Meylan* (Hutchinson)	37	1.47	1.30	1.45
Meylan* (Prince)	47	1.42	1.30	1.41
Milbank*	39	1.30	1.28	1.52
Mount*	45	1.17	1.18	1.21
Nebo*	32	1.47	1.39	1.59
Neff*	36	1.42	1.33	1.86
Parisienne*	36	1.41	1.30	1.52
Payne*	44	1.31	1.34	1.72
Payou*	26	1.61	1.42	2.63
Placentia*	40	1.31	1.25	1.59
Persian*	49	1.18	1.18	1.36
Pomeroy*	54	1.08	1.09	1.34
Prince*	36	1.33	1.22	1.80
Prolific	37	1.32	1.25	1.77
Rush*	45	1.27	1.17	1.33
Santa Barbara*	39	1.32	1.27	1.20
Santa Rosa*	38	1.38	1.28	1.59
Sinclair*		1.31	1.28	1.45
Sorrento* (Italian)	49	1.11	1.08	1.55
Teague	50	1.23	1.17	1.37
Treyve*	37	1.34	1.22	1.45
Ward*	45	1.20	1.13	1.50
Weaver	60	1.03	1.03	1.31
Wiltz*	37	1.48	1.43	1.78

PROPAGATION.

The problem of the best way to propagate the walnut is of long standing, though for obvious reasons the present interest is greater than at any time in the past. Nearly a hundred years ago (1818) Thomas Andrew Knight, writing of the propagation of the walnut, said:

> The advantages of propagating varieties of the walnut tree by budding will, I think, be found considerable, provided the buds be taken from young or even middle-aged healthy trees; for, exclusive of the advantage of obtaining fruit from very young trees, the planter will be enabled to select not only such varieties as afford the best fruit but also such as endure best, as timber trees, the vicissitudes of our climate. In this respect some degree of difference is almost always observable in the constitution of each individual seedling tree, and this is invariably transferred with the graft or bud. * * *
>
> The buds of trees of almost every species succeed with most certainty when inserted in the shoots of the same year's growth. But the walnut tree appears to afford an exception, possibly in some measure because its buds contain within themselves in the spring all the leaves which the tree bears in the following summer, whence its annual shoots wholly cease to elongate soon after its buds unfold. All its buds of each season are also, consequently, very nearly of the same age, and long before any have acquired the proper degree of maturity for being removed the annual branches have ceased to grow longer or to produce new foliage. * * *

There are at the base of the annual shoots of the walnut and other trees, where those join the year-old wood, many minute buds which are almost concealed in the bark, and which rarely or never vegetate but in the event of the destruction of the large prominent buds which occupy the middle and opposite end of the annual wood. By inserting in each stock one of these minute buds and one of the large and prominent kind I had the pleasure to find that the minute buds took freely, whilst the large all failed without a single exception. This experiment was repeated in the summer of 1815 upon two yearling stocks [with equal success]. * * *

The most eligible situation for the insertion of buds of this species of tree and probably of others of similar habits is near the summit of the wood of the preceding year and, of course, very near the base of the annual shoot; and if buds of the small kind above mentioned be skillfully inserted in such parts of branches of rapid growth they will be found to succeed with nearly as much certainty as those of other fruit trees, provided such buds be in a more mature state than those of the stocks into which they are inserted.[1]

Later (1832) Mr. Knight said:

The walnut tree appears hitherto to have effectually baffled, under all ordinary circumstances, the art of the grafter. * * * [It] may be propagated with more success by budding. I have succeeded tolerably well in some seasons and in one season perfectly well, but in several others not a single inserted bud has been found alive in the following year, though all had been inserted with the greatest care.[2]

Mr. Knight also stated that he found the following mode of grafting perfectly successful in 1831 under many unfavorable circumstances: Allow the primary buds to unfold on both stocks and scions; then remove the opened buds, and after the small secondary or tertiary buds, which have been previously almost invisible, begin to swell, take off the scions and immediately insert upon the stocks, which should be of wood of the previous year. Saddle or cleft grafting is equally successful, though with both modes of operating it is advantageous to pare away almost all of the wood of the scion, the large pith of the young walnut in this case being of no inconvenience to the operator.[3]

The French author Berthet,[4] writing upon this topic some years ago, said:

It is noticeable that the walnut, especially when not grafted, seasons very often; that it is to say that the harvests are not equal from year to year; an abundant harvest may be followed by a very poor one.

Speaking of the importance of grafting as a means of propagating the walnut, J. B. Neff,[5] a grower of high-grade stock and originator of the Neff nut, says:

The average seedling walnut orchard is not a success for several reasons: The nuts are uneven in size and form, the trees are not equally productive and are largely subject to blight. It may be said that one-fourth of the trees produce a few nuts, another one-fourth produce about enough to pay the expenses of their own care, thus leaving one-half to pay such profit as may be obtained from the whole.

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[1] Transactions of the Horticultural Society of London, ser. 1, vol. 3, 1820, pp. 133–135.

[2] Idem, ser. 2, vol. 1, 1835, pp. 214–215.

[3] Idem, pp. 215–216.

[4] Annales des l'Institut National Agronomique, sér. 2, 1897, p. 34.

[5] Personal communication.

From this statement, which appears conservative, of the views held by one of the best-informed growers of the Pacific coast, the profits of an orchard of seedling trees are not over one-half what they should be if the trees were grafted. The profits on an orchard of grafted trees should be considerably larger if judicious care is taken in the selection of both varieties and stock. If it be true that seedling trees are more liable than grafted ones to attack by blight bacteria, it is probable that the revenue would be more than double that derived from the average seedling orchard. It must be kept in mind that there is much difference of opinion among growers and propagators as to what are the best stocks and varieties for specific localities. Much of this divergence of opinion among leading growers is due to the fact that experimentation in the propagation and improvement of the walnut in the United States is in the earliest stages.

Notwithstanding the success of Mr. Knight in budding the walnut, the method of propagating commercially has been to plant the nuts, except to a limited extent as in the Grenoble district, where the practice of grafting some of the best strains of the Mayette, Franquette, and Parisienne has been followed for some years.

The earliest walnut orchards of California were grown from nuts purchased in the open market. After these orchards began to bear it was noticed that some trees produced more and better nuts than others. Then followed a period in which the growers selected nuts from trees that were heavy bearers or that yielded a product of a higher quality, better form or color, thinner shell, or earlier maturity. This seed-selective method poduced several improved varieties, some of which should be propagated with a greater degree of certainty than is possible by seedage.

It has been found that the walnut is like the apple, the pear, the peach, and the plum; there are only two ways of propagating a variety with certainty—by budding and by grafting. Thus, it has come about after centuries of cultivation that advanced students and successful growers agree that budded or grafted trees should be used in starting a commercial orchard. Trees true to name are now propagated almost exclusively by grafting, but experiments during the past year or two by several propagators, notably Kraus, of Oregon, indicate that budding will soon take rank with if not supersede the grafting process.

STOCKS.

The two important elements in propagating the walnut true to type, variety, or name are the stock and the scion. The consensus of opinion is that the two native black walnuts, together with the rock walnut of Texas, are the stocks par excellence on which to graft the Persian walnut. The most enlightened propagators and growers recommend *Juglans rupestris* for Texas and the Southwest; *J. californica*, southern form, for the foothills and interior valleys of southern California; *J. californica*, northern form, for the coast region and interior valleys of northern California and southern Oregon, including the Umpqua Valley; *J. nigra* or *J. californica*, northern form, for the Willamette Valley in Oregon and the Columbia Valley in both Oregon and Washington; and *J. nigra* for the eastern United States. Further investigation of the merits of these stocks through extended plantings may modify these conclusions, particularly as to interior California and the Willamette and Columbia Valleys.

R. Wiltz, a propagator of considerable experience, in discussing the merits of stock for California, says:

> For our conditions in general I am convinced that the northern California black as a stock for the Persian can not be excelled. It grows 40 to 50 per cent faster than the eastern black, has a vegetative season four to six weeks longer, is inured to our conditions through ages of natural selection, is one of the deepest rooted trees that we have, is a rapid grower, has thus far been free from diseases, is exceedingly prolific under the most trying conditions, and readily accepts grafts of all strains of the Persian.[1]

Harvey C. Stiles says of *Juglans rupestris:*

> It is a very handsome tree, well worth growing for its beauty, shade, and fruit, but its great value lies in its use as a stock on which to work the English (properly Persian) varieties. * * * On that root English walnuts are succeeding in parts of California and Arizona where they failed utterly on their own roots. * * *
>
> The English walnut is very intolerant of mineral soil salts even at considerable depth and the trees, even after growing well for several years, will die back when the roots reach such soil strata. On the other hand, this *rupestris* is found almost only in a natural state on strongly mineralized soils and in hot arid regions.[2]

G. A. Schattenberg,[3] writing of the walnut industry in southwestern Texas, states that the English walnut on its own root vegetates too early in the spring for his region. He says that the future of walnut growing in Texas lies in the use of *Juglans repestris* top-grafted, and that a few trees of *J. rupestris* top-grafted with the variety Franquette have made in eight years a growth of 10 feet and have borne in succession four or five crops of fine nuts without irrigation.

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[1] Personal communication.

[2] Stiles, Harvey C. Walnuts in Southwest Texas. Bulletin 2, Texas Dept. of Agriculture, 1908, p. 43.

[3] Schattenberg, G. A. The Future of the Walnut Industry in Southwest Texas. Bulletin 2, Texas Dept. of Agriculture, 1908, p. 42.

Since the above was written (1907) Mr. Schattenberg finds that his Persian walnut grafts on *Juglans rupestris* suffered severely in recent winters and particularly from autumn frosts. These results cast doubt on the opinions previously expressed, and the suggestion is here offered to use caution in planting the walnut in localities not fully tested.

F. T. Ramsey, Austin, Tex., says:

> Three or four years ago it occurred to us that English walnuts could be successfully and profitably grown by budding upon our native walnuts. We have been over 30 years trying to grow them upon their own roots, but have failed to obtain a nut. Four years ago we obtained direct from the woods some small trees of our native dwarf walnut, which we call *Juglans rupestris*, and after they had stood a few weeks in the nursery row we budded them. The first year we obtained a growth of about 6 inches, but since then they have grown from 3 to 6 feet each year. We now have nearly all of the California varieties, besides the Rush, Hall, and Nebo from Pennsylvania. One of these trees, Franquette, set a nut last year, but it was accidentally destroyed before maturing. We find by "ring budding" that the walnut may be propagated with ease. Thus far summer droughts and unexpected frosts have not injured a single tree. Our native walnuts vary considerably. Some trees produce a nut the size of a small marble, while others produce them half the size of an eastern black. I have been distinguishing these by the names *Juglans rupestris minor* for the small one and *J. rupestris intermedia* for the larger one. We find that the English buds will grow from two to four times as rapidly upon the former as upon the latter during the first year, so far as observed. This *minor* variety often bears a heavy crop while only 3 or 4 feet tall; the best of them can hardly be called trees, though some of them reach the height of 20 or 30 feet. I believe we will find good, profitable walnut orchards growing all over the prairies from here to Kansas.[1]

Should the expectations of Mr. Ramsey be realized by half, great value will attach to *Juglans rupestris* stock, but it must be kept in mind that these views are based on very limited experiments.

GROWING THE STOCK.

The nuts for stocks should be selected from robust, vigorous, healthy, fruitful trees of the desired species, growing under conditions that prohibit cross-pollination. After being harvested they should be layered or planted where rodents will not molest them. The method of layering will depend upon the quantity to be handled. If the quantity is small, they may be layered in the manner usually followed by nurserymen—in flats or shallow boxes easily handled by one person. If the quantity is large, lay a plank floor on the leeward side of a building with sides 6 or 8 inches high; cover the planks with 2 inches of clean, moist sand, spread a layer of nuts, over these an inch more of sand, and continue until all the nuts are layered. On the topmost layer of sand place a light covering of straw, shavings, or leaves to prevent wash or drift, and over all stretch a fine-mesh wire netting to keep out rodents.

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[1] Personal correspondence, 1911.

In the spring as soon as sprouts issue from the opening nuts they may be taken from the layering bin and planted in the nursery in the same manner as though unsprouted. As the young shoots are very brittle, extreme care must be exercised in planting; otherwise considerable or even irreparable injury results. If the ground about the nursery site is free from the depredations of rodents, the nuts should be planted at once, in regular nursery rows, upon harvesting or receiving them.

The nursery site should be high, well drained, with an open exposure and a soil that is deep, friable, and fertile without excess of humus. Unless the subsoil is thoroughly porous, the ground should be prepared by deep plowing and subsoiling. The rows should be 4 feet apart and should lie east and west, so that in the operation of budding the buds may be readily inserted on the north side. In planting the nuts they are placed about a foot apart in the row and 1 to 3 or 4 inches deep, according to the species. The small nuts of *Juglans rupestris* may be planted not more than 1½ inches deep, the larger nuts of *J. californica* and Paradox may be safely placed at 2 to 3 inches, and the still larger nuts of *J. nigra* and Royal at 3 to 4 inches. In planting nuts in the nursery rows the first stages of growth of the young trees may be facilitated by placing the nuts with their sutures in a vertical plane. As the root and shoot both issue from between the opening valves, it is readily understood how this may enable the seedling to effect an erect position almost from the moment of its germination, thereby hastening its appearance above ground and thus promoting its first stages of growth.

NURSERY TILLAGE.

Give the young trees such tillage as will insure a fine, powdery, surface soil. Care should be exercised at all times to avoid rolling clods against the young trees and thus diverting them from an erect growth, or by bruising the bark or terminal buds. If grown in a good soil thoroughly tilled, 30 to 50 per cent of the seedlings will be large enough for crown grafting the following spring. A conservative grower would discard the remainder.

SCIONS.

The scion wood should be selected with extreme care, as much or more than is accorded the selection of the stock. Only the best of trees should be drawn upon for scion wood. Trees that are tainted with blight, that are imperfect pollinators or that mature their staminate and pistillate blossoms at separate dates, that are indifferent bearers, that are unthrifty growers, that have a sprawling irregular habit, or that are prone to fitful activity in the spring should be avoided. From suitable trees take the normal 1-year-old wood from the middle more or less erect portion. Under no circumstances use suckers, water sprouts, or trailers. Such wood rarely produces fruit, and though there is no direct evidence against it, the presumption may be advanced that it is not the best for the purpose. Scion wood should be one-fourth to three-eighths of an inch in diameter, straight, clean, thrifty, plump about the buds, tubular not angular, with short internodes and small pith, preferably not over a foot long, which is long enough, without using the terminal bud, for two or three scions. This statement is not intended to imply that wood of greater or less length than 1 foot is not suitable for grafting but rather that the kind described is ideal. Often the later growth of a season is not properly ripened; hence the frequent unfitness of terminal buds, especially on growth over a foot in length. Scions should be cut during the period of dormancy, probably two or three weeks before vegetation begins, say February or March, according to location and season. Immediately after cutting, the cut ends should be dipped into melted paraffine or other tenacious and impervious substance, so that evaporation from the cut part may not reduce the vitality of the scion. After the cut ends are waxed or smeared tie the scions in small bundles, wrap with moist moss or vegetable fiber, and put in a cool place until needed. Occasional inspection should be made to insure against attacks of fungi, such as molds, in case the temperature of the receiving space becomes too high. Another method of preserving scions practiced in California is as follows: In a box on a layer of clean moist sand 2 inches deep place a layer of scions, chink between these additional sand, then another layer of scions and more sand, and so on until the layers of scions are 2 to 3 inches deep, and cover all with 2 inches of sand and set the box away in a cool place. Occasionally examine the soil to see that it does not dry out and shrivel the buds, and on the other hand avoid moisture sufficient to start the buds prematurely.

TOOLS.

Perhaps the most important part of grafting is to have first-class tools. The knife for preparing stocks and scions, especially in trimming the cambiums, should be of the best material, so that a sharp edge may be constantly maintained. Other tools, such as a splitting knife (which may be a heavy long-bladed butcher knife), a shoemaker's knife for nursery grafting, a budding knife of the usual form, a double-edged saw, and an oilstone with one face of emery, should likewise be of the best material. Additional tools are a mallet, two or three small wedges of iron or hard wood, a wax pot with a warming device, a wax brush, cotton cloth, twine, bicycle tape, and cloth parcel tags. The wedges should be 6 or 7 inches long and of different widths to use with branches of varying size. The shape of the taper should be such that the edges are thinner than the middle. A wedge of such form will keep its position in the cleft and may be removed readily at the close of the operation by a slight sidewise movement without disturbing the scions. A galvanized-iron pail or coal-oil can with the top cut away and four wires stretched across, two each way at right angles 8 inches from the bottom, will serve as a support for the wax pan. The space below the wires holds a gasoline blowtorch, or a fire may be built in the bottom on a layer of earth or puddled clay to keep the wax melted.

GRAFTING.

The details of methods of grafting by leading propagators differ, but not enough to be considered distinct systems. The instructions here given are adapted from George C. Payne and R. Wiltz. The principles applied to grafting deciduous fruit trees apply to the walnut, but the following precautions should be observed: (1) Great care must be exercised to have dormant wood for scions; (2) the grafting must be done just as the leaf buds of the stock are unfolding; (3) the cambium of stock and scion must be brought into exact contact; (4) the cleft in the stock for the reception of the scion shall be clean cut and so made as to grip the tongue of the scion firmly; (5) the scion shall be made from carefully selected wood with a clean, smooth-cut tongue; and (6) the wound shall be covered with adhesive wax or paste impervious to water or air[1] until the union of stock and scion is fully effected. The treatment of the wound necessitates frequent inspection in order that rewaxing may be done where cracking or melting may permit air to reach the cut surface of stock or scion. Nothing must be left undone to insure an air-tight graft and to prevent evaporation from the scion.

Numerous modes of grafting and budding have been employed with the walnut and among the more successful are cleft, saddle, whip-and-tongue grafting; annular, flute, prong, shield, and chip budding.

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[1] In the walnut-grafting operations at the Arlington Experimental Farm in the spring of 1912, plasticine or modeling clay was used with excellent results. In fact, a larger percentage of successful grafts was obtained with plasticine than with wax, as the former does not dry and crack like the latter.

The time for grafting is just as the trees begin to vegetate, or while the leaves are unfolding. If top-working the Persian walnut, it is advisable to begin operation somewhat earlier than if grafting the black-walnut stock, as the former has a more abundant sap flow during the first few days of vegetative activity. It is possible to successfully graft the black walnut after the leaves have quite fully unfolded, while best results with the Persian stock are obtained by grafting just as the buds are fully swollen. The grafting of nursery stock is attended with variable results. In some years propagators are widely successful, during other seasons only a few obtain favorable results. No satisfactory explanation has been made for this uncertainty, though most propagators ascribe it to seasonal conditions and to lack of specific information for the problems in hand. The operator should avoid bleeding nursery stock by grafting as soon as possible after the slipping of the bark and discontinue before the sap becomes free flowing. Budding may be done at any time when the bark will slip readily and when well-formed dormant buds can be procured.

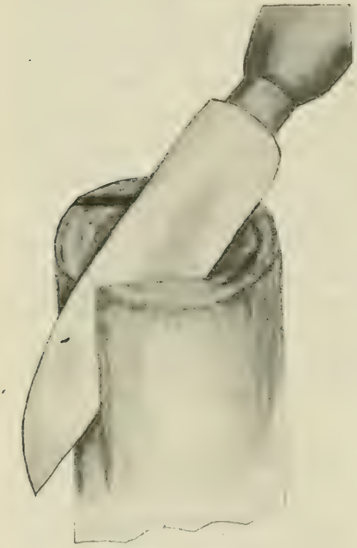

FIG. 1.—Cleft grafting: First position of the knife when making a cut.

The following directions for cleft grafting will apply in all essentials to the other modes of grafting: Prepare the stock which, preferably, should be not more than 2 or 3 inches in diameter, by making a smooth, clean-cut surface. In top-working old or large trees it is often desirable to graft limbs of a diameter larger than 3 inches, in which case additional care must be exercised in the operation and more scions set in each stock. In sawing off the stock use great care not to split the bark. If the stock to be sawed off is a substantial branch of a full-grown tree the same care must be given as in pruning; otherwise back splitting will

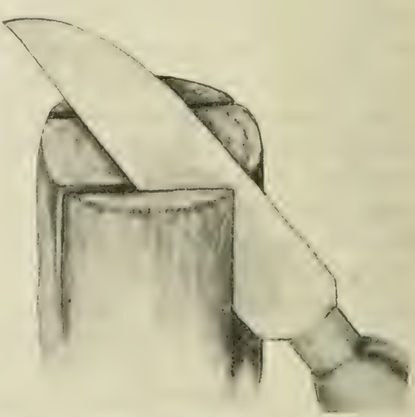

FIG. 2.—Cleft grafting: Second position of the knife when making a cut.

occur, with great inconvenience to the operator and damage to the tree. To avoid back splitting, follow the directions for removing large branches in pruning (p. 83). After the stock is prepared, split it along two lines (figs. 1 and 2), using care to keep the knife in the positions shown, so that as it is driven into the stock it will cut the bark first; if the stock is large, split it along four lines (fig. 3).

After the bark has been split $1\frac{1}{2}$ to 2 inches deep on both sides of the stock, change the knife to the third position (fig. 4) and complete the cleft.

If a horizontal branch is to be grafted make the cleft crosswise rather than vertical, so that the scion may be inserted on the side. Scions inserted upon the upper face of a branch rarely grow, while those on the sides do quite as well as when placed upon vertical branches. After removing the knife insert a small wedge to hold the cleft open until the edges can be smoothly dressed and the scions inserted (fig. 3).

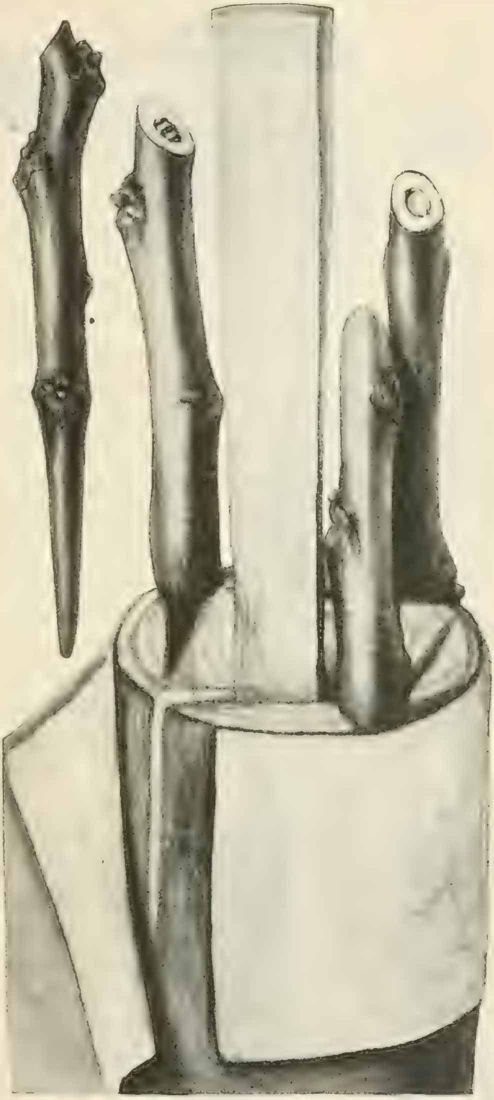

FIG. 3.—Cleft grafting: Large stock of Persian walnut split to receive four scions. The clefts are not made entirely across the stock; i. e., each split is made from one side only.

PREPARING THE SCION.

If the scion wood has been properly selected it will be an easy matter to make two or three suitable two-bud scions from each of the sticks of scion wood. Where the wood is not uniformly good, select only that which has little pith, strong but not large buds, and firm wood. The lower end of

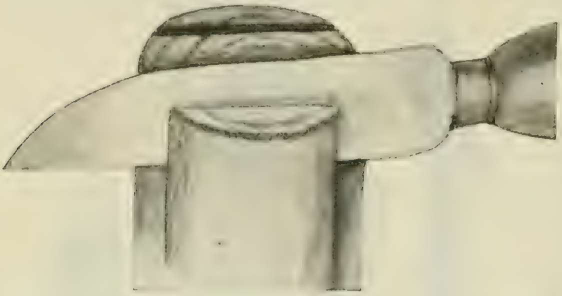
FIG. 4.—Cleft grafting: Third position of the knife when making a cut.

the scion should be 1½ to 2 inches below the lower bud, the upper end one-fourth to three-eighths of an inch above the second bud of the scion. The tongue of the scion should be about 1½ inches in length, of an easy, straight taper, and with the outside somewhat thicker than the inside (figs. 5 and 6). In placing the scions use the utmost care to have the tongue of the scion fit the cleft snugly, and so placed that the cut edges of the inner bark of both stock and scion come in contact over as long a space as possible. On removal of the wedge the cleft will firmly grip the scion and safely hold it till the operation is complete. The final step is to wrap the stock firmly with a cotton band (fig. 7) 3 or 4 inches wide and to cover with wax the entire wounded surfaces of both stock and scions, including all breaks in the bark at the base of the cleft. If the cleft remains widely open after the wedges are removed the space may be choked with old newspaper or similar material before the stock is waxed over. This packing should be pushed below the cut surface of the stock so that waxing will leave no breaks whereby air may enter. After waxing is complete (fig. 8) draw over the whole a paper bag (fig. 9) and tie it firmly about the stock a few inches below the lowest point of the cleft. When the scions indicate that union has taken place, the cotton band may be

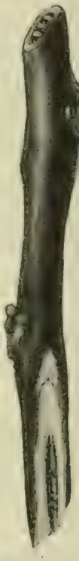
FIG. 5.—Cleft grafting: Scion prepared for insertion.

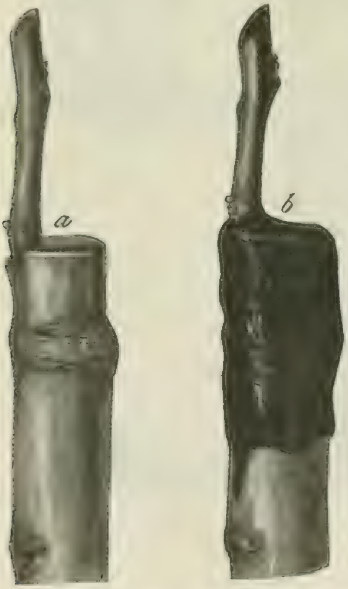

FIG. 6.—Cleft grafting: *a*, Scion inserted in the cleft; *b*, the completed graft wrapped and waxed.

cut through at one or two places to prevent restricting the circulation of sap. The other modes of grafting differ from the above only in minor details (figs. 10 and 11).

CARE OF THE GRAFT.

It is necessary in grafting and budding that no air reach the cambium of either scion or stock. Frequent inspection of grafts should be made and all pores and cracks rewaxed. If the waxing was well done at the start and the paper bags carefully adjusted and firmly tied it is not likely that much rewaxing will be needed. As soon as the grafts are nicely started the bags may be broken open, preferably on the north side, so that light may be admitted. In a few days thereafter the bags may be entirely removed. As soon as the grafts are well established provision must be made for supporting them against winds. For this purpose strips of lumber 1 by 2 inches are firmly nailed to the stock in such positions as will permit of tying the young growth to them. As the growth of grafts, especially when placed upon large and vigorous stocks, is very strong, these supports need to be from 8 to 12 feet long in order to give the desired protection (fig. 12). The grafts should be tied with strong soft cord or cloth bands in such a way as to prevent rubbing. During this time all sprouts nearer the grafts than 2 feet must be kept pruned off. Only in the case of grafts that have failed to take should sprouts be allowed to grow near the point of grafting. In this case one or two such sprouts may be used for budding, thus enabling the operator later in the season to make a second attempt at propagation.

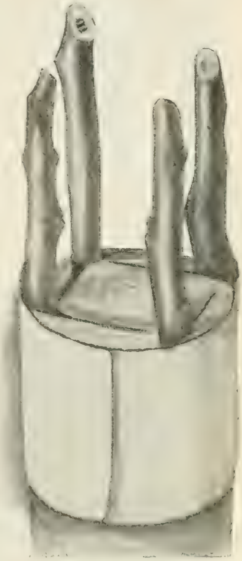

FIG. 7.—Grafted stock wrapped with a plain or waxed cotton band.

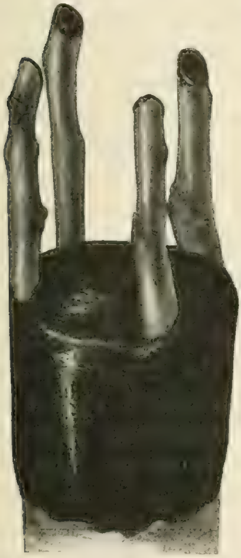

FIG. 8.—Completed cleft graft covered with wax.

BUDDING.

Thus far budding has been practiced only by amateurs. More or less experimenting was done the past decade and few propagators found it commercially useful, but with the rapid spread of the idea that only grafted or budded trees should be planted for orchards came a corresponding growth of interest in budding. Several persons investigating independently within the past two years have produced excellent results from carefully selected buds, modifying in several respects the methods usually adopted in budding (figs. 13 and 14.) While not sanguine enough to publish results, some experimenters believe that we are soon to witness a decided change in the method of budding, which will displace, especially in nursery propagation, the present unsatisfactory practice of crown grafting. During 1910 less than 20 per cent of the nursery grafts effected successful union, and in a few instances propagators who had formerly secured as high as 50 to 60 per cent of unions were rewarded with less than 10 per cent. The low percentage of "takes," together with the heavy expense of operation in crown grafting, makes it desirable to adopt another method.

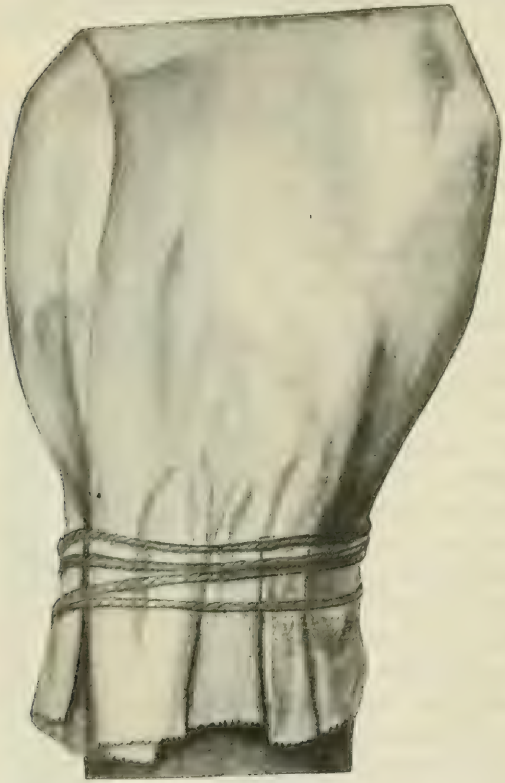

FIG. 9.—Completed cleft graft covered with a strong paper bag to protect it from evaporation. This bag should be removed when the scions have made considerable growth.

To stimulate experiment along this line, attention is called to a few points found useful last year. One worker found that the use of dormant buds upon the present year's growth during July resulted favorably. He adopted the usual method of budding, but made the crosscut at the bottom instead of at the top of the slit. Another recommends chip budding (fig. 15), with bicycle tape[1] for wrapping material. This operator finds it necessary to use buds that are fully dormant, preferably those which have been kept in cold storage, but if such buds are not available, then use secondary or tertiary buds formed early on the present season's growth. Some propagators recommend plate budding (fig. 16), and exhibit highly satisfactory work done by this method. One propagator working by this method selects stocks 1 to 1½ inches or even larger in diameter and takes buds from stocks, shoots, or branches that are one-half to three-fourths of an inch in diameter. He recommends that the operation be performed as late as possible to get a good flow of sap when the weather is cooler (an important factor); growth for the season is about completed, and the wrapping used may remain on all winter. Prong budding (fig. 17) was highly recommended by the late B. M. Lelong, of California, and is strongly indorsed by a few skillful workers on the Pacific coast. In all these instances the prime requisite appears to be the dormancy of the bud followed by close wrapping and sealing to protect the wound from the air.

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[1] Bicycle tape gave very unsatisfactory results in budding operations at the Arlington Experimental Farm in 1912.

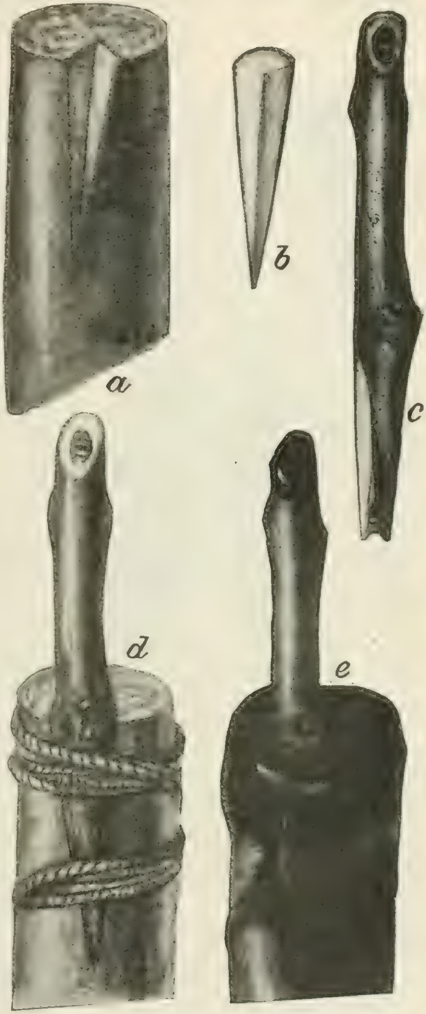

FIG. 10.—Modified wedge grafting: *a*, Stock with wedge removed; *b*, wedge to be discarded; *c*, scion with lower end shaped to replace discarded wedge; *d*, scion fitted into stock and wrapped with cotton twine; *e*, completed graft with wax covering.

Recently E. J. Kraus,[1] of the Oregon Experiment Station, as a result of extensive experiments in budding the walnut, states in substance that the method of budding consists in the combination of the old principles adapted to new subjects and conditions. By this method with good buds, 1-year-old seedlings, and the exercise of ordinary care, 70 to 90 per cent of the buds should take and form satisfactory trees.

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[1] Circular 16, Oregon Agricultural Experiment Station, 1911, p. 3.

Briefly stated, Kraus's instructions for accomplishing such results in Oregon are as follows:

The best stock was the California black; the hybrids were found to be not dependable; buds of the present season's growth were found to be unsatisfactory for several reasons; plump buds 1 year old were found best. These may be taken from the base of the current year's growth or from scion wood cut during the winter and kept fully dormant. Such bud wood should be placed in moist sand about two weeks before budding is to be done. The T and inverted T methods were found unsatisfactory, and the hinge and flute bud were used. Special care is needed in the wrapping and waxing to see that it is pressed firmly against the wood of the stock and that the air is excluded; tie the buds into place with raffia, then cover with waxed cloth; if budding is done in hot weather it is desirable to tie a paper sack over the bud for protection; in about 10 days remove the wax and this outer protection; about a week later cut the raffia band; use care to see that the raffia is neither left too long on fast-growing stocks or cut before the bud has united firmly.

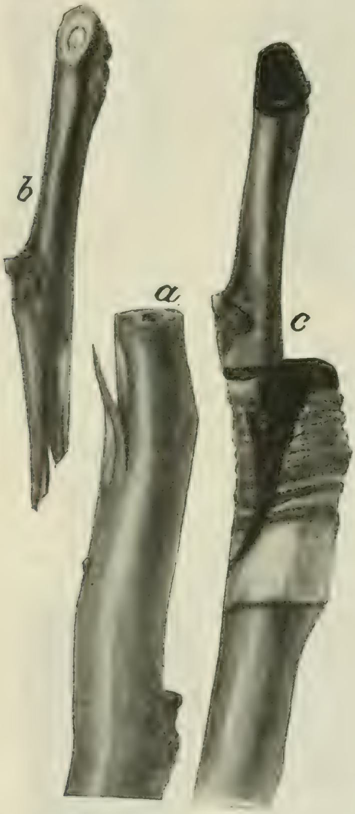

FIG. 11.—Modified whip grafting: *a*, Stock prepared to receive scion; *b*, scion with lower end shaped to fit into stock as prepared; *c*, scion fitted and held in place by twine wrapping and protected by wax covering.

The following details as to the method of hinge budding and pushing the bud under protection are distinctly different from those given by the older authors:

Making the bud.—About 1 inch above the surface of the soil make a transverse incision about half an inch long, and a similar one about three-fourths of an inch above this. Connect the two with a longitudinal incision. This forms the completed I cut on the stock. It is very desirable to use extra care in making these cuts. The ideal condition is to merely penetrate the bark just to the wood but not to cut into it. The bud, which is rectangular and of exactly the same length as the distance between the two transverse cuts on the stock, is removed from the bud stick by first making two transverse cuts the proper distance apart to give the correct length to the bud, and then connecting these with two longitudinal cuts about half an inch apart. The bud is then easily removed by gently inserting the back of the knife blade under one corner of the piece of bark and prying up, when it will be found that it will readily part from the bud stick. No wood should be removed with the bud and care should be taken when the bud proper is extra large to avoid pulling the soft wood or core out of it. It may be necessary in such a case to first loosen the bark containing the bud on one side up to the bud proper, then carefully cut this soft core with a knife, and the remainder of the bud piece may be easily removed. As soon as the bud is removed from the bud stick it should be immediately inserted into the stock. This is readily accomplished by first carefully turning back the upper corners of the I-shaped cup, slightly prying them away from the wood, then inserting the base of the bud into the opening, pushing it down until the top and bottom of the bud are flush with the transverse cuts on the stock, and the bud lies smoothly and snugly against the latter. By making the bud force its own passage under the bark of the stock after this manner there is much less exposure to the air than if the sides of the cut are first turned back and the bud then laid in place. The bud is now ready for tying and waxing as explained below.

Starting the bud into growth.—If the budding has been done in June or earlier and the buds are to be started into growth the same year, the trees should be headed off at the time the raffia is removed, about 15 days after the budding. Cut off the stock about 1½ to 2 inches above the bud, allowing the top to remain attached at one side by a small piece of wood or bark. These tops should then be broken over and laid overlapping each other in the row, thus providing shade to the buds and aiding in the carrying off of excess sap and preventing to a considerable degree an excessive sprouting from the root. In about two weeks the scion bud will have started into active growth. The top of the stock should then be removed entirely, close to the bud. In sections subject to high winds the young shoots should be staked. See that all buds and shoots from the stock are taken off, as they are a material drain on the reserve food supply in the stock.

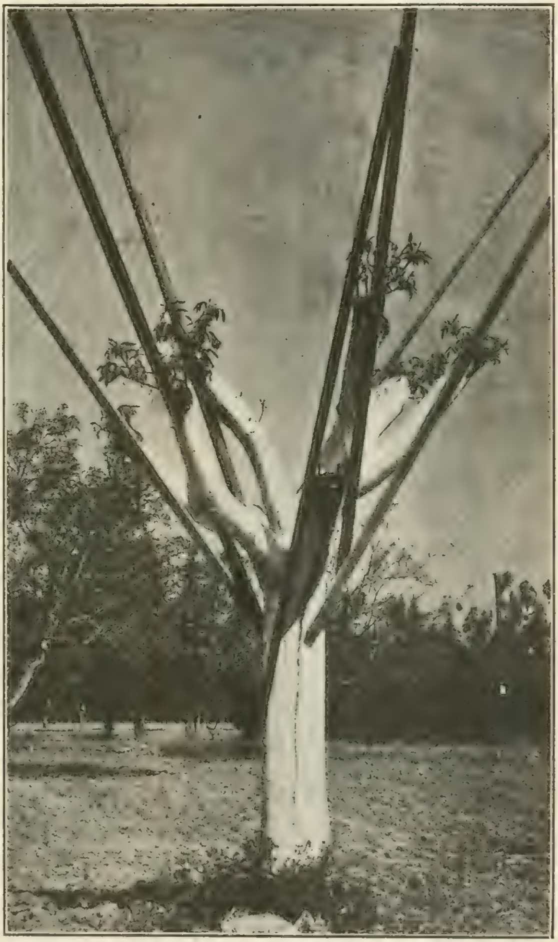

FIG. 12.—Stays applied to a top-worked walnut tree to prevent the growing grafts from being blown away or broken off by their own weight. (Photographed by J. B. Neff.)

If the budding has been done late in the season so that the trees can not be headed back before August 1, such heading back had best be deferred until the following spring just about the time that growth starts. There is some danger of the buds being killed during the winter or injured by excessive wet weather. It is therefore preferable in such cases to put the buds somewhat higher on the stock than when the trees are to be headed back in June or July. Trees coming from stock headed back about the middle of June to the first week in July will make from 14 to 20 inches' growth the same season and usually mature thoroughly, so there is no danger of killing back during the winter. Such young trees could be put on the market the winter following the budding. Trees from stock that has been headed back in the spring will make a straight growth of 5 to 7 feet during the season.

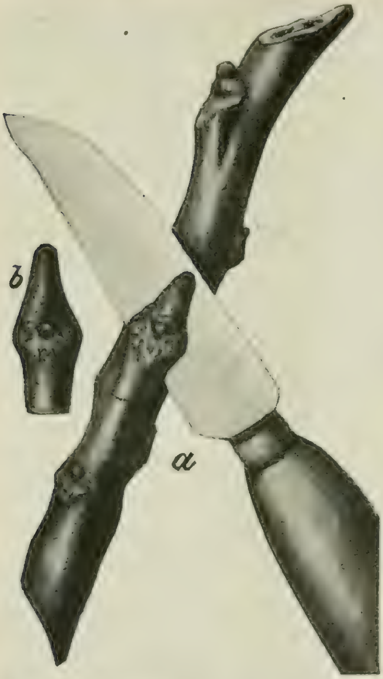

Fig. 13.—Budding by the T, shield, or slip process: *a*, Cutting the bud from the bud stick; *b*, the bud after removal.

WAXES.

The following recipes for waxes are substantially from the several propagators cited:

Beeswax 1 pound, rosin 5 pounds, flaxseed 1 pint, lampblack 1 ounce; melt the mixture. The object is to get a wax that is soft enough to be pliable without running; a little practice will soon show whether the wax needs more or less oil.—*J. B. Neff.*

Rosin 4 parts, beeswax 2 parts, tallow 1 part. Cut the materials up into small pieces, mix well, and boil for several minutes. Dip the hands in linseed oil before using this wax.—*Wright, a Texas grower.*

Linseed oil 1½ pounds, beeswax 1½ pounds, rosin 9 pounds; or, linseed oil 1 pound, beeswax 2 pounds, rosin 9 pounds. Tallow would answer in place of the oil, but the oil is better. Heat over a slow fire until all materials are fully melted and unified, but do not boil.—*R. Wiltz.*

Rosin 5 pounds, beeswax 1 pound, finely pulverized charcoal one-half pound, raw linseed oil 1 gill. Melt the rosin and beeswax over a slow fire, then stir in the charcoal, add the oil, and pour into pans that have been previously oiled with linseed oil so that the wax will not stick.—*G. C. Payne.*

PLANTING, TRAINING, AND PRUNING.

The leading problem with every orchardist is, What are the best varieties to plant? While preferred varieties may be indicated, selection in each instance must depend upon the judgment of the individual. Upon this point some light may be shed by the remark of one of California's foremost students of the walnut. When asked, "What varieties are best for me to plant?" he said: "I do not know. If you will come to my home I will show you what I have done, give you the whole story, and then you can draw your own conclusions." Those who contemplate planting walnut orchards will do well to visit the successful growers of the district where they contemplate planting. Within tentative boundaries the types that have given and promise to give the most favorable and certain returns are here indicated.

For the southern California region the six blight-resistant varieties suggested by the University of California:[1] Chase, Concord, Eureka, Franquette, Mayette, and Wiltz, though the Franquette is affected by blight in some districts. The Franquette and Mayette have been tried to a limited extent in southern California but so far as reported with rather indifferent results.

For northern California: Concord, Franquette, Mayette, Meylan, Wiltz, and possibly Parisienne and Treyve, though Mr. Hitchinson, the only grower of Treyve, reports that it is late in coming into bearing and yields light crops—two serious faults. The Eureka is also urged by some observers as especially worthy of trial in this district.

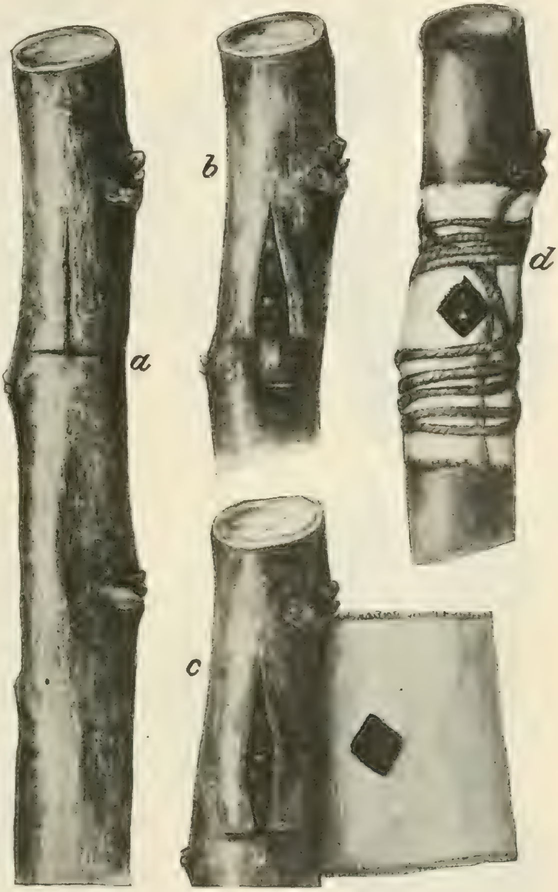

FIG. 14.—Steps in the process of T, shield, or slip budding: *a*, Stock with inverted T-shaped slits in bark prepared to receive bud; *b*, same with bud being slipped into place; *c*, bud in place ready to be wrapped; *d*, bud showing through cut in wrapper when process is complete.

For western Oregon and Washington: Franquette and Mayette are the only varieties yet given extended trial, but Concord, Meylan, Parisienne, Treyve, and Wiltz are well worth general testing in an experimental way. Of Concord, Groner says: "This variety is too late for our environment."

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[1] Bulletin 203, California Agricultural Experiment Station.

For the Eastern States: Only one variety, the Pomeroy, has been generally disseminated. As a seedling it has been given a thorough trial. It is apparently suited to the climate of the more favorable sections of the Eastern States and will undoubtedly yield a more uniform product and better results when worked upon the eastern black walnut. The Nebo and Rush varieties, recent introductions which promise well, are being worked on native stock, and are the only eastern varieties of which grafted trees are offered for sale at present, though others will probably be offered in 1913. A few other varieties give promise of meeting local requirements for a hardy, productive, marketable nut of fair quality, notably Cumberland, Holden, Milbank, Mount, and Sinclair. Trees of the Bijou type have proved in several instances to be hardy and good croppers, but the nut, though suitable for home use, is not considered of commercial importance. It is expected that experiments under way will in a short time demonstrate the fitness of some of the hardier European strains, particularly when top-worked upon the native black walnut.

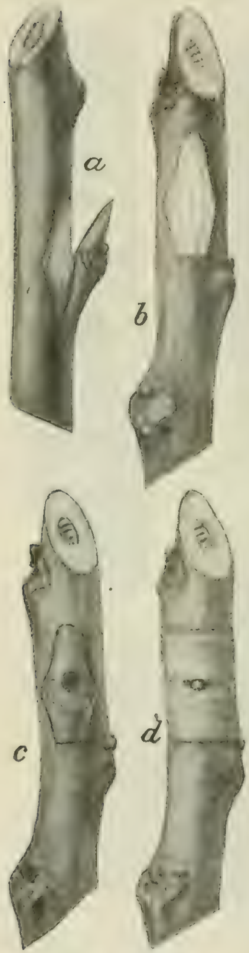

FIG. 15.—Steps in the process of chip budding: *a*, Bud stick with bud partly removed; *b*, stock with bud removed and discarded, ready to receive new bud; *c*, new chip bud from bud stick in place on stock; *d*, bud wrapped as it appears when operation is complete.

POLLINATION.

Before deciding what varieties to plant, ample pollination must be assured, as otherwise generous crops can not be produced. The walnut normally produces two kinds of blossoms: The staminate, commonly spoken of as the catkins, and the pistillate, usually called nutlets (fig. 18, *a* and *b*). This arrangement of the sex organs on two separate parts of the plant, together with the peculiar structure of the flower, necessitates the employment of an outside agency—the wind—to insure pollination. The staminate blossoms, when open, are much expanded (fig. 19, *a*) and heavily charged with dustlike pollen released from little sacs (the anthers) and blown upon the stigmas of the pistils (fig. 18, *d*), thereby effecting fertilization. Not infrequently these two kinds of blossoms (staminate and pistillate) do not mature at the same time upon the same tree, or one or the other of them is infertile because of imperfect development: such tree, if by itself, is unproductive. The Los Angeles or Mission walnut, when planted in the northwestern Pacific region, persistently fails to fruit for one or other of these reasons, though occasionally failure is chargeable to late frosts.

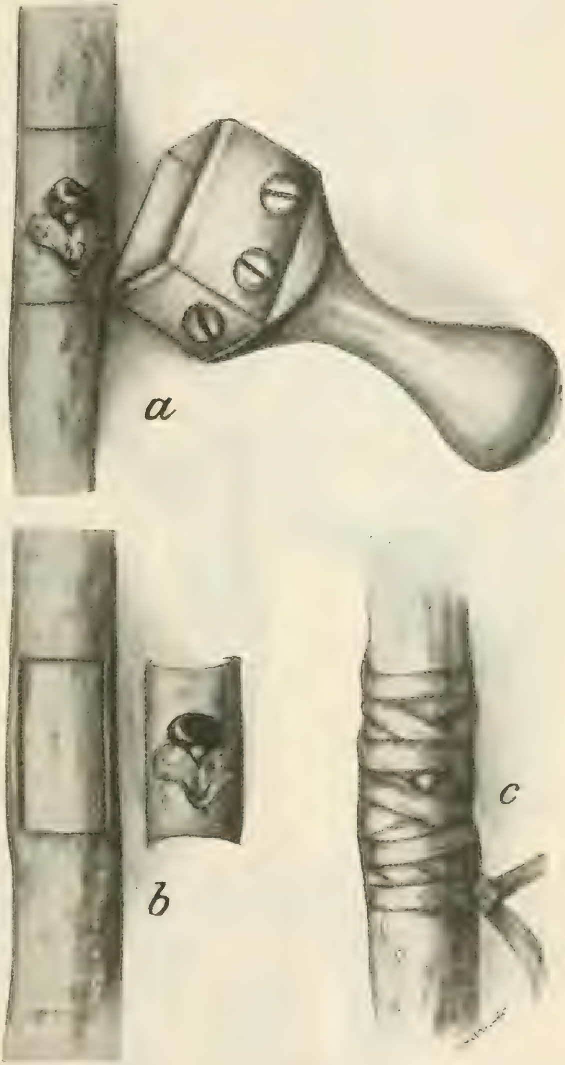

Fig. 16.—Plate or partial ring budding: *a*, Bud stick showing bud marked for removal by special tool used for the purpose; *b*, stock with patch of bark removed and discarded ready to receive new bud; *c*, new bud in place and wrapped with raffia, completing the process.

To insure complete fertilization care should be exercised in the selection of varieties. Where little definite information about pollination and fertilization is available it is safe to plant two or more varieties which blossom at the same time. In some instances of shy bearing it may be desirable to introduce a variety rich in pollen, regardless of the character of its nuts, in order to amply fertilize the blossoms of the more valuable varieties. To insure effective pollination one tree in seven when planted in quincunx and one in six when planted in squares is deemed sufficient, except possibly where prevailing winds are strong and persistent from one direction. Many

American growers are of the opinion that future orchardists will make provision for insuring a high percentage of fertilization by mixing varieties. Until ample investigation has been made it is safe to plant only varieties of known value as pollinizers, leaving the work of testing varieties not so well known to the State or Nation, except as the enthusiastic amateur finds it advantageous to make trials of promising new varieties.

So far as recorded by American growers only two varieties, the Santa Barbara and the Franquette, have been planted in pure stands of any considerable area. With these two varieties crop shortage appears not to be due to insufficient pollination, but no definite experiments have been performed to ascertain whether better results might be obtained if opportunity for cross-pollination were afforded. California growers after many years of experience consider the crop better in those orchards where more than one variety is grown. In the case of the Santa Barbara the type, vigor, and individuality of the trees vary as widely as several different varieties ordinarily do, insuring nearly as active cross-pollination. Briefly, then, it may be stated that while good crops may be secured from tracts planted to single varieties, especially if free blossoming with catkins and nutlets at the same time, progressive growers advise mixed plantings of two or three varieties of similar merit, keeping in view that they should be equally well adapted to the location and blossom at the same time in order to insure effective pollination.

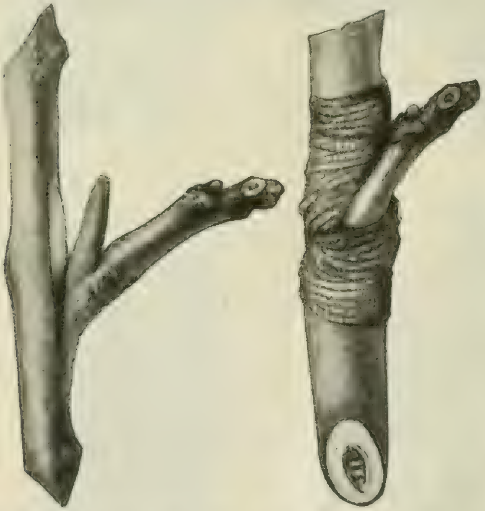

FIG. 17.—First and last steps in the process of prong budding or prong grafting.

PLANTING.

The walnut is planted as early in spring as the soil permits, care being exercised to avoid puddling when the ground is too wet. The distance between trees varies from 40 to 60 feet each way, requiring 12 to 27 trees to the acre. Some growers recommend planting trees in the center of the squares made by the first alignment, such trees to be removed as soon as those in the regular rows require the space for their development. It is asserted that the increase of product.

if grafted trees are planted, will pay a liberal profit upon the additional cost involved in the purchase and planting of the extra trees.

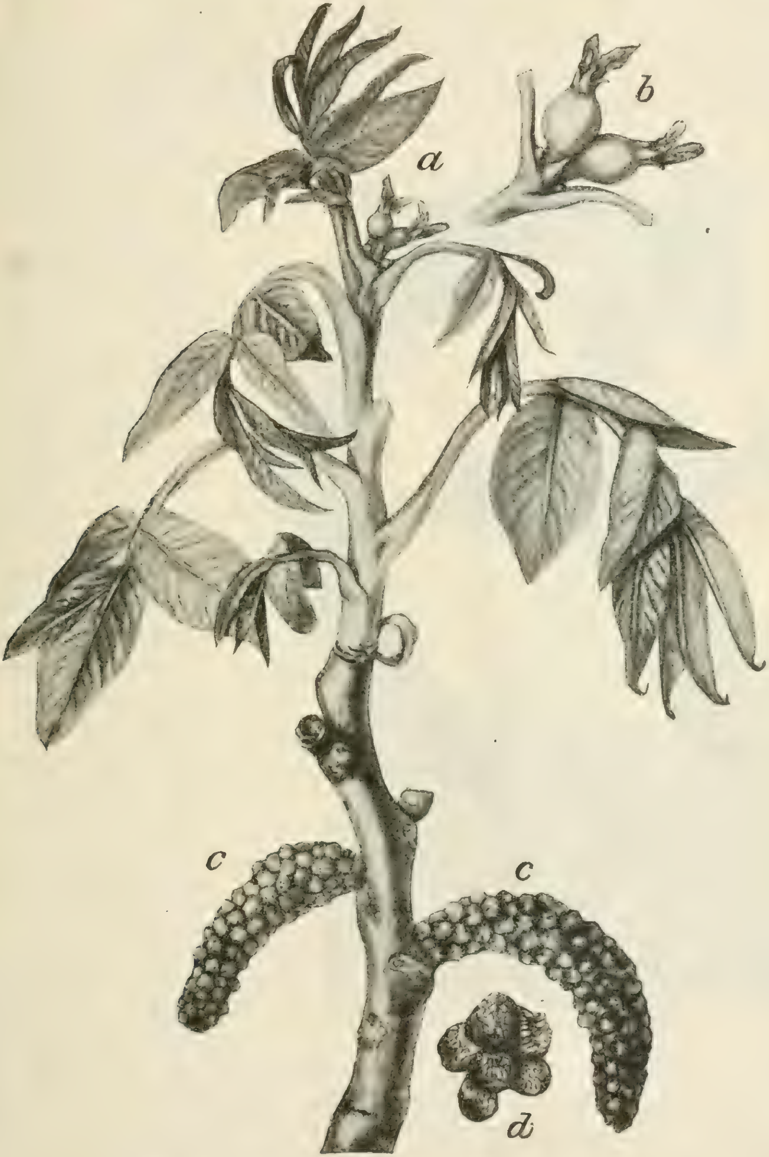

FIG. 18.—Young shoot of Persian walnut with a piece of the previous year's growth, showing staminate and pistillate flowers in situ: *a*, Pistillate flowers; *b*, the same enlarged; *c*, staminate flowers; *d*, portion of same enlarged.

Only deep, rich, well-watered soil should be used for growing a walnut orchard, and the filler trees should be removed as soon as the regular trees are 16 to 20 years old.

Formerly much difference of opinion existed as to the age at which trees should be transplanted from the nursery, but recent practice favors 1-year-old trees that have been grafted on stocks 1 or 2 years old. Such trees average 4½ to 6 feet in height and an inch, more or less, in diameter 1 foot above the union of the stock and scion and may be taken from the nursery with a larger root system than when older. Since trees at this age will be unbranched, the grower will be able to adjust the branches that form the head to much greater advantage than if transplanting is delayed until after branches have formed in the nursery. The walnut does not suffer so much from malformed heads as some other deciduous orchard trees, but a well-formed head is desirable if vigorous and long-lived trees are to be grown.

The details of planting are quite the same as for other orchard trees. Keep the roots from air as much as possible between nursery and orchard. Prune off all bruised and broken roots with a clean, smooth, oblique cut. If possible to obtain trees from the nursery in the autumn preceding planting, root pruning may then be done advantageously before the trees are heeled in, and the wounds will be callused before planting time. The growth of the new rootlets can then proceed more quickly at the opening of the season. In recent years much discussion has arisen over the importance of the taproot. It is safe to say that healthy vigorous trees with a good supply of lateral roots and a short piece of taproot will make as good development as one with a longer taproot. The removal of the taproot is not

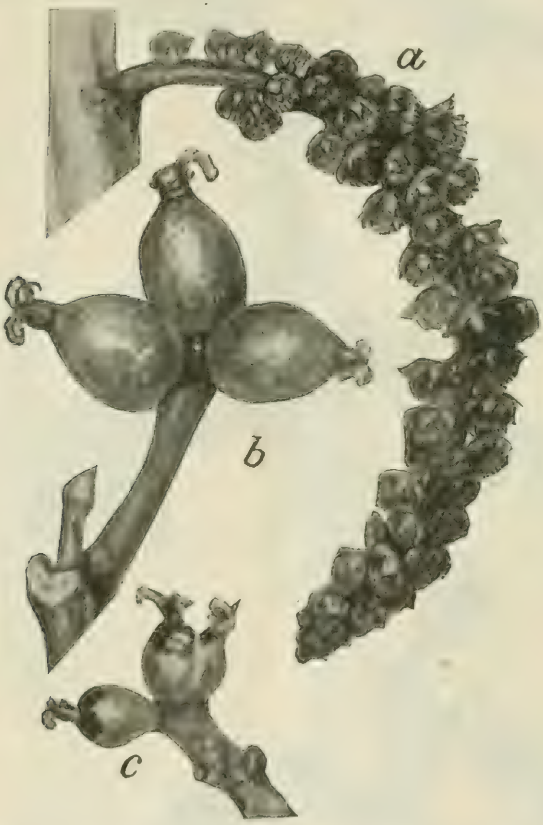

FIG. 19.—Sexual organs of the Persian walnut: *a*, Matured catkin; *b*, fertilized, unblighted nutlets; *c*, blighted nutlets of the same age.

prohibitive of the success of transplanted trees, especially if they are not more than 2 years of age.

TRAINING.

The subsequent treatment of the young tree will depend upon the end to be attained. If the head is to be formed high the tree must not be cut back, but must be supported in an erect position by a tall, strong stake 2 by 3 inches in cross section and 8 feet long (fig. 20). If it is decided to form a low head the top may be cut back to 4 or 5 feet and a short stake driven to hold the stock upright until the branches are well formed and the trunk of sufficient strength to support the head. When the young branches have issued a few inches the trees should be examined and only those shoots permitted to grow that will help to form a strong, symmetrical head. The young main branches allowed to grow should issue 9 to 12 inches apart on the trunk and be so supported, if need be, that they will grow obliquely upward. After the 3 or 4 main branches have become fixed in the desired positions little remains to be done in training or pruning except to remove the sprawling growth from the lower side of the outspreading branches and such wood as threatens to rub, interlace, or unduly crowd (fig. 21).

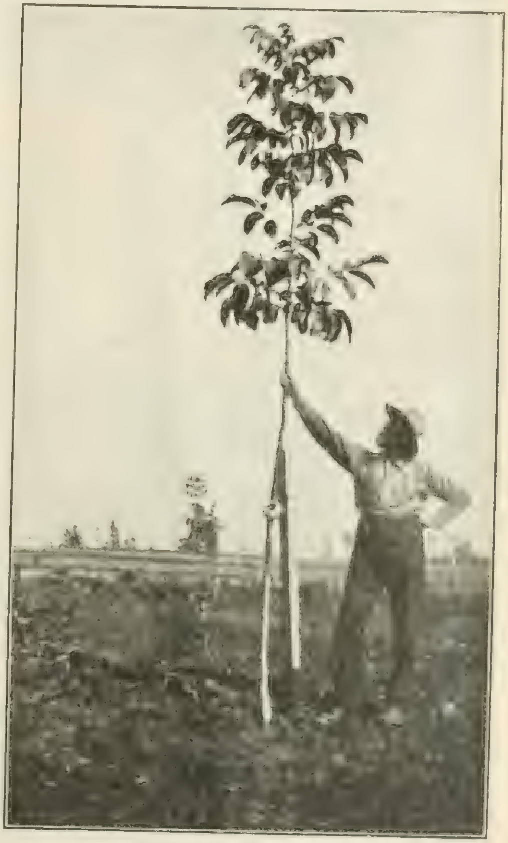
FIG. 20.—Young walnut tree staked and tied—a general practice with high-headed trees in Oregon.

In sections where the summer heat is not too intense the walnut should be pruned to present an open, spreading head, facilitating the formation of bearing wood throughout the top rather than on the outer portions, as is usual with dense heads. Where the summer temperature rises to 110° or higher it is necessary to train close or dense heads to protect the nuts from sunburn, which darkens the kernel and lessens the market value.

It was formerly the practice to head the trees 6 to 9 feet high, but now many start the heads at 4 to 5 feet. In pruning and training during the first few years this lowness of branching is of considerable advantage. The fact that the walnut tree is wide spreading has led many to suppose it necessary to head high in order to facilitate tillage and harvesting beneath the branches. By proper training the head may be started low and the branches still be kept well out of the way. (See frontispiece.)

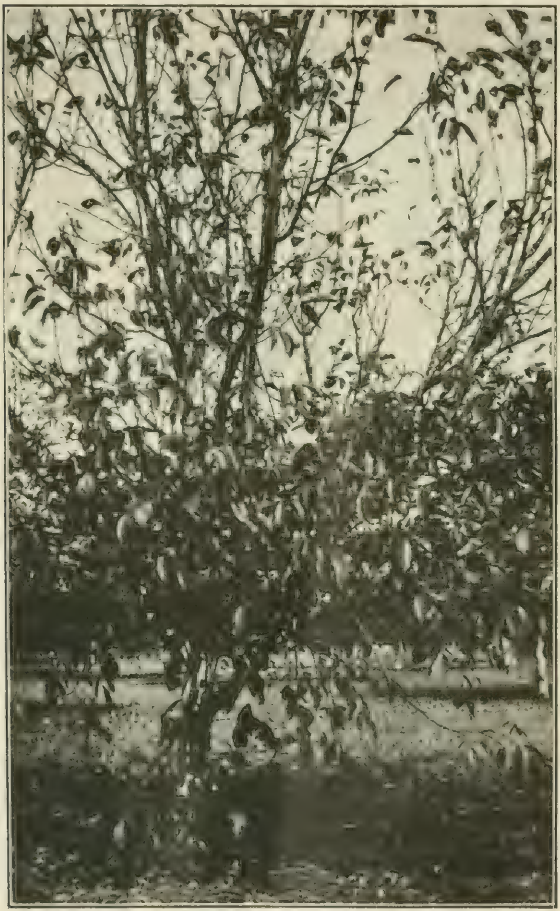

FIG. 21.—Unpruned Persian walnut tree with an abundance of trailers.

Low spreading branches and close heads favor blight, while high open heads permit free circulation of air and penetration of sunlight which are unfavorable to the development of blight Low heading at 4 to 5 feet does not necessarily imply that the tops shall be low. They may be quite as high and open as though the heads were started at 7 to 9 feet from the ground. In the first instance pruning, forming the head, and training the branches can be performed more effectively, with a saving of both time and labor. The importance of the proper structure of the head does not usually appear until heavily laden mature trees are wrecked by an autumn storm.

Little pruning and less training has been done in the past, but more attention is now given to these matters. Growers are studying the young trees in newly planted orchards and are debating how to stimulate growth, increase the yield, and lessen the effects of blight by judicious pruning. Specific treatments are being tested, such as thinning out the centers of the tops, lifting the outspreading portion of the head by pruning off the lower limbs, and in some instances removing lateral branches, all insuring the tree more light and air and a better distribution of bearing wood.

As the area of cultivation becomes extended and the varieties under cultivation are augmented by the addition of types developed to meet local conditions, which are practically numberless, it is certain that extended and varied practices in pruning and training will be evolved.

PRUNING.

The walnut actually requires very little pruning. Root pruning and cutting back attendant upon planting have been referred to under training: such other pruning as is found necessary or desirable to keep the tree in form for the best results should be done during the resting period and at least two or three weeks before the starting of the sap in spring, so as to permit the wounds to become dry and to prevent bleeding and a tardy healing of the wound. If close attention is accorded the tree in all matters pertaining to its proper training it will rarely be found necessary to remove other than small branches. Should it become imperative through accident, oversight, or other contingency to take off a large branch, care should be exercised to prevent the splitting or tearing of the part remaining.

The removal of a large limb may be best effected by cutting it off in sections. In order to prevent back splitting, bruising, or crushing make a deep saw cut on the under side of the limb some distance out, then upon cutting into it from the upper side a few inches farther out the limb will break short off. Another operation will dispose of the stub and leave a clean-cut surface close to the main body. In any event make the final cut so that no projecting stub is left.

Upon the removal of any branch over an inch in diameter cover the wounded surface with quick-drying adhesive paint, such as a good quality of white lead and linseed oil, in order to keep the surface dry and prevent the attacks of fungi. This paint will be of greater efficacy if the wound is first brushed with a strong solution of one part of copper sulphate to three parts of water. From time to time go over the orchard with a paint pot and brush and renew the covering on these wounds to prevent fungi from obtaining a foothold.

During the first few years of growth of the walnut it is prone to develop many drooping shoots from the lower branches. These are often used for bud or scion wood, but the practice is to be deprecated. Such shoots rarely if ever bear on the parent tree and it is possible that the continued use of such wood may induce a habit of drooping growth and transmit barrenness. Until investigation definitely disproves the idea it is safe to avoid such practice.

CULTIVATION OF THE ORCHARD.

Clean tillage is the almost universal practice, except as to cover and truck crops. Cover crops are coming into general use for blanket and humus purposes and truck crops are grown among young trees. In the large orchards of southern California where clean tillage has been practiced 15 or 20 years the soils are becoming less tractable because although tons of leaves fall upon the ground in the autumn only a small proportion of them become incorporated with the soil. They blow away from the smooth surface of the orchard floor into ditches, fence rows, and hedges and are largely lost to the orchard area. Cover crops are useful to hold these leaves in place as well as to furnish humus and to prevent wash from winter rains. With cover crops, the first operation in the spring is to plow under such crops to a depth of 6 or 7 inches. This operation may be followed at once with a spike or spring tooth harrow and then with a roller or clod masher if the condition of the soil demands it. This first or spring preparation of the soil should be followed by frequent scarifyings, once every 10 days or 2 weeks, to kill weeds and to convert the surface into a dust mulch to better conserve the water supply. These operations are usually performed by riding cultivators with broad-winged shovels or with an implement known in California as a scarifier, having broad blades set obliquely to the line of draft, each one partly overlapping the course of the one ahead of it (fig. 22). From years of experience many of the large California growers in districts where the annual rainfall is over 24 inches are convinced that it is better to maintain a thorough dust mulch throughout the growing season than to irrigate, though frequently one application of water about two weeks before the nuts begin to fall is of service in causing them to separate more readily from the hulls.

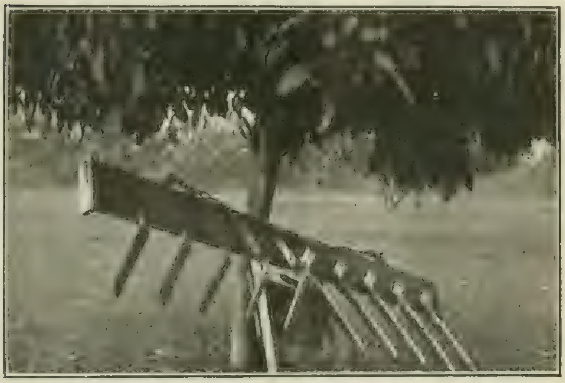

FIG. 22.—A harrow used by California cultivators to produce the dust mulch much employed in the groves of that State.

IRRIGATION.

The details of irrigation are much the same as for orchards of other deciduous trees. The site, soil, location, and season are in each instance governing factors. Present irrigation of the walnut is confined to the section of California south of Ventura and to the interior valleys. The furrow system is generally used in orchards where the soil is heavy and the basin system where the soils are light. In districts where a mild climate will permit and the soil is deep and retentive, winter irrigation may be practiced with decided benefit.[1] Where the rainfall is 17 to 23 inches two applications of water are advised, one in February and one in May. In very dry seasons a third application before harvesting is desirable to prevent the hulls clinging to the shells. Possibly the machine huller will be more economical than an application of water.

COVER CROPS.

Some years ago several growers in southern California noted that the nuts from the older orchards were averaging smaller, one year with another, than those from young trees. Experiments with a few trees and in one instance with a large orchard, that of John F. More, of Goleta, showed frequent applications of cover crops to be of decided benefit to old orchards. It is becoming apparent to owners that provision must be made to supply plant food to the soil if the trees are to maintain the crop standard in quality and quantity.

The selection of a cover crop will depend upon the location. Mr. More found barley and volunteer plants sufficient; others find it desirable to use some leguminous plant to obtain nitrogen. In the Pacific Northwest vetches will probably give the best returns. If the land is well supplied with nitrogen and needs only humus and a protection from beating rains or wash, then any of the winter-growing crops like mustard, wheat, rye, or winter oats will serve the purpose. In parts of California vetches, winter and hairy, fenugreek, Canada field peas, bur clover, sweet clover, and volunteer plants such as alfilaria, mustard, and others are available.

As to the expense and management of cover crops the following by Samuel Fortier[2] is especially pertinent:

> In the walnut groves of Orange County, Cal., bur clover is sown in the fall, given one or two irrigations during the winter if the rainfall is below the normal, and plowed under in April.
>
> The cost of such cover crops as peas, vetch, or clover includes the seed, the labor of sowing it, the water, and the time required to apply it. These items, according to Dr. S. S. Twombly, of Fullerton, Cal., amount to $2.50 to $3.25 per acre. Twenty tons per acre of green material is perhaps an average crop. In this tonnage there would be about 160 pounds of nitrogen, which at 20 cents per pound represents a value of $32 per acre for a cover crop like vetch.

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[1] Irrigation of Orchards. Farmers' Bulletin 404, U. S. Dept. of Agriculture. 1910.

[2] Idem, p. 35.

FERTILIZERS.

The question of fertilizers for the walnut orchard is one that has not yet attracted wide attention. In recent years owners of old orchards have found some form of manure necessary to insure thrifty growth and a substantial crop. While cover crops are desirable and serve to ameliorate and improve the soil and increase its fertility, something more appears to be needed in soils long covered with bearing orchards.

In France, where the problem is of long standing, Fallot cites Rouault's formula[1] as approximating its own calculations for a chemical fertilizer suitable for walnut culture, as follows:

Nitrate of soda containing 15 per cent of nitrogen, 78 pounds; superphosphate containing 12 per cent of phosphoric acid, 16 pounds; and chlorid of potassium containing 48 per cent of potash, 6 pounds; total, 100 pounds.

In the article cited M. Rouault[1] says:

> Now, are not these three substances most appropriate to the soils and to the needs of vegetation? Would it not be an advantage also to adopt a manure mixed of farm manure and chemical substances in a manner to give it a composition approaching that which I have indicated?

After making numerous analyses of the walnut and an extended study of the soils of France, Fallot[2] states:

> The walnut is rich in nitrogen and contains considerable proportions of phosphoric acid and potash. In regions where intensive culture has been adopted it will be an advantage to use fertilizers containing nitrogen, phosphorus, and potash in proportions varying with the needs of the tree; that is, depending on the quantities of fertilizing elements which the tree removes from the soil and does not restore. As regards the walnut, the fruit alone takes out these elements; one can neglect the small proportions remaining in the wood, and the leaves in general return to the soil either directly or after having been utilized as litter.

While Fallot says that the French walnut is especially rich in nitrogen and makes the composition of the whole nut nitrogen 2.66 pounds, phosphoric acid 0.75 pound, potassium 0.79 pound, analyses by G. E. Colby, of the University of California, give nitrogen 0.54 pound, phosphoric acid 0.15 pound, potassium 0.82 pound and show it rich in potash rather than in nitrogen.

The problem of fertilizers is complex. It is no longer held to be simply a matter of returning to the soil what the crop takes out, or of supplying those substances that analysis shows to be wanting in the soil. A half score of other factors as important as these enter into the problem of how to feed the orchard. A knowledge of the composition of soil and crop is valuable, and even more so are data pertaining to the physical conditions of the soil, its texture, component parts, aeration, drainage, humus and water content, biological factors, and the health, vigor, and yield of the plants growing thereon.

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[1] Rouault, M. F. Le noyer, recherches destinés à guider dans la composition des engrais qu'on lui destine. Grenoble, 1891. [Cited by B. Fallot.]

[2] Fallot, B. Culture du noyer. Journal d'Agriculture Pratique, t. 2, 1898, pp. 348–349.

Nothing short of practical trials of fertilizer materials will determine just what the needs of an orchard are. While cover crops perform excellent service in several ways, they must be supplemented in the older orchards with phosphoric acid, potassium, and possibly lime. As a result of extended work upon California soils, Dr. Hilgard advises that it will be safest to begin with phosphate; if unsatisfactory, apply nitrogen; and if anything further is needed, use potash.

Each orchardist must solve his own problem by varying the treatment to meet the different soil conditions. Granting that the soil conditions are of average adaptability to the walnut, specific requirements are a generous supply of humus, available nitrogen, phosphoric acid, and potassium, with ample aeration and biological activity. Cover crops supplemented by mineral fertilizers are usually most economical. Advice may be sought of the chemist of the State experiment station, and it is desirable to consult the experience and studies of station experts upon the various phases of orcharding.

As a series of first trials, it is suggested that one part of the orchard to include its various soil types be planted with a cover crop of legumes and another part with nonlegumes. On parts of each of these areas soon after growth has started use different minerals or mixtures, preferably plowed under or disked in with the cover crop. For example, about each of several trees, say from 12 to 20 years of age, use 5 to 15 pounds of superphosphate and about each of several others twice the amount. On another part of each cover crop area, leaving at least two trees between the different trial groups, give several more trees twice as much superphosphate. About trees of another group put 4 to 12 pounds of sulphate of potassium and about the trees in yet another group 8 to 20 pounds. To other groups supply a mixture of the two substances in the above proportions. Such tests varied by years or pursued more than one year should afford results of much value to the orchardist.

Ralph McNees, of Whittier, Cal., in a letter reporting his experience, says:

> My grove is located upon very deep, rich, dark clay soil. Until recently I have been able to secure enough stable manure to give my orchard a good dressing each year, which, with a crop of bur clover to turn under each year, has kept up the fertility of the soil and supplied the necessary humus without having to resort to the use of chemical fertilizers. Recently it has become difficult to secure sufficient stable manure, and I have depended upon the nitrogen-gathering cover crop to supply the necessary nitrogen and to bring up the potash with which our soils appear to be well supplied. In addition, I have added about

one-half ton of superphosphate per acre. At the same time I have used all the stable manure that I could readily procure. My crop varies but little from year to year, and orchards that were alternate bearers before are now under this treatment annual bearers. My aim with this treatment is to keep the tree vigorous and making good annual growth; this insures regular bearing and good crops. A fellow grower has accomplished the same or even better results by growing an annual crop of vetch, and after irrigating it by the furrow system whenever necessary to insure a full crop plows it under in July. Of course the character of the soil, the number and age of trees per acre, cultivation, and irrigation will all tend to influence the yield. But two conditions are evident in the vetch treatment: First, an increased amount of available nitrogen; second, a largely increased humus content; both of which are important factors in walnut growing.

INTERCROPS.

Should an intercrop like beans be grown, a not uncommon practice in parts of southern California while the trees are young, returns from such crop may be expected to net $20 to $50 per acre, while the straw and chaff are returned to the soil as fertilizer. In some sections tomatoes, cabbage, squash, melons, and similar crops are grown among the trees during the first few years. Potatoes, beets, and similiar root crops attract gophers, which eat the young roots of the trees and do much damage. The returns from intercrops vary, but approximate the returns from the bean crop under like conditions. Under exceptional local or seasonal conditions the income from the melon or tomato crop may be materially larger, and in an exceptionally poor year the returns from the intercrop may be nothing at all.

It must be kept in mind that the intercrop is taken off merely as a loan upon soil resources that properly belong to the orchard and that if too long or intensively continued the practice may work to the disadvantage of the trees. If the intercrop must be grown restitution may be made by cover crops and fertilizers.

FILLERS.

Fillers are sometimes used instead of intercrops to occupy the soil more completely during the earlier years. The practice involves extra outlay, but may yield a corresponding revenue. The filler crop varies with the district. In California it may be peaches, plums, prunes, oranges, or lemons; in Oregon, prunes, early-bearing apples, or cherries. It is seriously debatable whether on the whole it is not better to avoid the use of fillers entirely, though much depends upon the individuality of the orchardist. Within bounds fillers may be employed to advantage, but if allowed to prejudice the normal development of the main crop they become an injury not compensated by the income which induces its employment. Not only do fillers require the care and attention of the cultivator at the same time that they are needed by the main crop, but they draw heavily upon the food and water resources of the soil as they become older. With the owner's interest temporarily occupied with the crop that brings the earlier returns it frequently occurs that he overlooks the fact that the main crop, though yielding little or no revenue, requires to be supplied with ample food, water, sunlight, and air, all of which are being taken from them by the activities of the filler crop. If fillers must be utilized let it not be forgotten that additional food and water supplies must be provided if the principal and the secondary crop are both to succeed.

PESTS AND DISEASES.

BLIGHT.

The walnut serves as host to several insects and a few fungi, but the records indicate that few of them are serious foes to the tree or its fruit. Among those that do considerable damage year by year, blight or bacteriosis is most destructive. The bacterium causing this disease was discovered and named *Pseudomonas juglandis* by Newton B. Pierce, formerly of the Department of Agriculture, while conducting research investigations in plant pathology in southern California in 1896. For a few years prior to that date, and even since its discovery, this organism had been a menace to the walnut industry, particularly of this southern district. At present, evidence of the blight is found in nearly all localities of the Pacific coast, where the walnut is cultivated commercially. It has also appeared in several parts of New Zealand with disastrous results, but is not elsewhere reported.

The damage is manifest chiefly in the young shoots and nuts. The affected shoots wilt, turn black, and die back from an inch to a foot or more (usually 3 to 6 or 8 inches). On young and rapidly growing trees the injury is often very serious, though as yet no record has been made of a tree being killed by blight. The injury to the nuts occurs about blossoming time, when there is little development, and the very small nuts fall from the tree. Those attacked at any subsequent date may either fall or remain until the tree is poled, depending on the virulence of the attack. Poling is performed by shaking or striking the limbs with a long pole having an iron hook at the end.

The disease attacks the hull from the outside (fig. 19, *c*) and gradually passes inward, destroying more or less of the shell—though often only discoloring it, in which case the nut remains on the tree—and later shriveling and blackening a part or all of the kernel. Blighted nuts usually fall prematurely, but sometimes remain on the trees to the end of the season. Figure 19, *b*, illustrates a group of unblighted young nuts of the same age as figure 19, *c*.

Blight appears with the first vegetative activity in spring and develops rapidly in moist warm weather. The period of most destructive activity usually lasts not more than 10 days. In 1910, at

Saticoy, where fog prevails to a far greater extent than at Santa Paula, the orchards were much less seriously affected.[1] Saticoy is nearer the ocean than Santa Paula, and perhaps the temperature during early growth was more favorable.

That blight has become a disturbing factor in the crop output of the California walnut orchards is evidenced by the fact that one firm with an established bearing orchard of 500 acres has removed the trees from 65 acres and is seriously contemplating the clearing of 75 to 100 acres more because the blight is particularly destructive in that part of the orchard.

Well-known orchardists in charge of large properties assert that the loss from blight in 1910 approximated one-tenth of the crop. The fruit of some trees was injured to the extent of 10 per cent, of others 60 per cent, while some were but slightly injured. The total loss, in round numbers, to the industry must have been over a quarter of a million dollars.

Both National and State Governments have realized for some years that the problem of combating the blight is serious, and each has conducted in its own way very complete investigations covering the subjects of remedies, especially the application of sprays. The investigators employed by both the Nation and the State are agreed that spraying offers no sure means of combating blight. Extended but incomplete observations made over widely separated areas indicate the possibility of partly overcoming the effects of blight by the use of fertilizers which stimulate the trees to an increased yield, and also that irrigation promises similar results.[2] Definite results from more extensive and completed experiments are awaited with much interest.

The latest findings relative to blight are by the University of California experiment station, from whose Bulletin 203 the following excerpts are taken:

> The ultimate solution of the blight problem appears to be in the growing of walnuts immune to the blight, desirable types of which are already in existence. Much work is being done at the Whittier laboratory in this direction. This involves the growing of grafted rather than seedling trees, and thus opportunity is given for choice regarding both the root and the top of the tree. Each is of great importance. Extensive plantings have been made at the laboratory of nuts of various kinds and sources for the production of root stocks. These represent several species of walnuts and also hybrids between different species. Experience has already shown that in the native California black walnut we have a more hardy root than that of the English walnut, one that is more capable of flourishing under unfavorable conditions and one with a much wider range of soil. The native walnut varies, however, in individual

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[1] Observation of C. C. Teague, president of the Southern California Walnut Growers' Association.

[2] Bulletin 203, California Agricultural Experiment Station.

trees almost as much as the cultivated species, so that there is room for careful selection and discrimination in growing a root stock. The California walnut is also divided more or less distinctly into two separate species. It may be classed as the southern California and northern California types. The tree which grows wild in the southern part of the State has its favorite habitat upon dry, somewhat elevated hillsides, with occasional trees in the valleys at the foot of these hills. It is distinctly a hillside rather than a valley tree, however. The tree itself has quite a shrubby rather than a treelike form, and even in large specimens grown on good soil with abundant water the tendency is still toward abundant branching rather than the formation of a tall, clean trunk. * * *

The origin of the northern California walnut is much in doubt. While this tree is one of the commonest grown for shade and ornament about many of the towns in central and northern California, yet there are only a very few places where there is any indication of the tree having been indigenous. Considerable attention has been given to this interesting question, and we have found but three locations where the walnut trees go back beyond the knowledge of any white person. These are (1) near Walnut Creek, Contra Costa County; (2) Walnut Grove, Sacramento County; (3) a point in the mountains of Napa County northeast of Napa City, near the top of the west slope of the so-called "Wooden Valley." In each of these places, and at no other which we can find, there were large, old black walnut trees growing at the time of the first white settlement. These primeval trees do not appear to have been indigenous to the localities where they are found, but the question of their origin is an extremely obscure one. Morphological and field studies are being made by Mr. Ramsey upon this subject. The northern tree shows a decided preference for a moist valley soil in the vicinity of streams rather than that of the south for growing on dry hillsides.

Both the northern and southern California walnuts have been found satisfactory as a root stock for the English, but we have as yet no sufficient comparison between them to judge finally as to which is the better. Such comparisons are now being made by this division by grafting English walnuts on various roots and planting them in various soils. The possibility of using for roots some of the not uncommon hybrids between the California black, American black, and English walnuts is also receiving much attention, on account of the extremely vigorous growth of these trees. Selected walnuts from all over the State as well as from other parts of the country have been planted at Whittier, and a very interesting nursery is in process of development.

The selection of a strain or variety of English walnut possessing immunity to the blight as well as desirable commercial qualities is receiving much attention. Immunity to this disease is not obtained entirely by actual resistance, but in many cases by simply escaping the worst infection period, i. e., the moist weather of early spring. Most of the immune trees are such as come out rather late in the spring, thus escaping rather than resisting the blight. Several of the ordinary French walnuts, such as the Franquette and Mayette, have this quality of lateness in an extreme degree, but this involves the question of the time of harvest in the fall, an extremely late crop not being desirable in California. The most promising trees found thus far are local seedlings of foreign varieties which develop somewhat later than our ordinary seedlings, but not so late as the French varieties mentioned. A number have been found which seem to justify their planting as blight immune. Among these we may mention varieties which have received the names Eureka, Concord, Chase, and San Jose, as well as the Franquette and Mayette mentioned above. All of these and many other varieties are being grown by this division and their value carefully tested for various portions of the State. We are now in a position to supply scions of all the important walnut varieties, as well as a limited number of nursery trees of some.

One very imperative phase of this matter has been the question as to the fate of the present existing plantings, consisting of many thousand acres of fine, large, thrifty trees, very satisfactory in every way except for the occasional loss of a considerable part of the crop through their susceptibility to the disease. Many of these orchards are extremely profitable even under present conditions, and it is evident that by increased attention to soil fertilization their productiveness can be maintained in a very satisfactory degree in spite of the disease.

One means of handling large trees which are extremely susceptible to blight is by top grafting them to the more immune kinds. The methods of doing this have received the consideration of this division, and much work has been done along this line. During 1908 and 1909 a considerable number of large trees were top-grafted, both by the station and by individual growers, with decided success. Experience elsewhere, particularly in the central part of the State where many large native walnuts have been grafted to the English variety, has shown that with reasonable success a new top equal to the original one can be put on a large tree in four years. In orchard work the most rational practice appears to be the picking out and working over of the trees most susceptible to blight each year until finally the whole orchard has been changed. In this way there is no marked loss from cutting off the trees in any one season.

Another method of working over an old orchard consists in intersetting with nursery trees of the California black walnut. It is more practical to plant the young trees rather than the nuts in the orchard. The object of this method is to grow the black walnut trees up to 3 or 4 years old and then graft them in the top to the desired variety. If the ground is closely shaded by old trees, they should be thinned enough to give the young black walnuts a chance to grow. This thinning can be done in most of our older orchards without any disadvantage, as in most of them the trees are already too thick. The young grafted trees will come into bearing early, and it is possible by this plan to have a new orchard well started by the time it is necessary to cut out the old trees. The advantage of a tree having the black walnut trunk as well as root is a very considerable one, owing to the susceptibility of the English walnut trunk to sunburn.

The extensive work by the University investigators entitles their views to great weight and those contemplating the planting of walnuts, particularly upon the Pacific coast, will do well to give them careful consideration.

SUNBURN AND PERFORATION.

The damage resulting from sunburn and "perforation" is occasionally serious enough to affect the value of the crop slightly. Sunburn blackens both shell and kernel, thus injuring the sale of the product. Perforation is denoted by the failure of the shell to fully develop or fill out. Sometimes the injury is in the nature of small openings through the shell: or, more frequently, very thin places. Both troubles apparently, are due to unfavorable physical conditions.[1]

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[1] A fuller discussion of sunburn and perforation will be found in Bulletin 218 of the California Agricultural Experiment Station.

INSECTS.

Occasionally other pests attack the walnut tree or its fruit, but no considerable damage has been reported. In a few instances the walnut aphis has caused slight damage. Other insects that attack the walnut are borers, which work in the trunks of the trees, several species of Lepidoptera, which feed upon the foliage in the larval or caterpillar stage, and the nut weevils, which feed upon the fruit and in some cases on the terminal twigs. Growers encountering insect pests should send specimens and damaged parts of the tree to the Bureau of Entomology, United States Department of Agriculture, Washington, D. C., with a request for information as to the ways and means for combating them.

HARVESTING THE CROP AND PREPARING IT FOR MARKET.

HARVESTING.

The most important phase of harvesting the walnut crop is to prevent the nuts from becoming stained. The market demands that the nuts be a clean, bright-yellowish hue. This requirement may be met in two ways: (1) By care in harvesting to prevent the shells from being soiled with dirt, stained with dye from the hull, or discolored by rains or strong sunlight; (2) by bleaching after being cured.

The outer hull of the Persian walnut ordinarily breaks along irregular lines when mature and permits the nut to fall free to the ground. During dry seasons part of the crop fails to do this or to fall from the tree at all until outside force is applied, usually in the form of poling or shaking. In normal years it is necessary to pole tardily maturing nuts to keep the harvesting period within reasonable limits. Such polings usually also require hulling.

By extreme care in harvesting it is possible to escape the need of bleaching. The natural color of most varieties if fully preserved is sufficiently light to meet the demands of all but the most fastidious purchasers. Let the grower exercise the following precautions: So far as possible gather the nuts just as the hulls open to free them. Allow none to remain long exposed to direct sunlight, rain, or dew, or in contact with the soil, or attached to parts of the broken hull. Let freshly gathered nuts remain for only the shortest time possible in picking boxes, sacks, or other receptacles before subjecting them to the cleaning process. Care must be taken that the nuts are not kept too long in water, as such treatment is liable to partly unseal them. A spray of water playing over a slatted revolving cylinder fully serves the purpose. Twelve to fifteen minutes' active rolling and rubbing is ample to remove soil particles and the hull fiber from the nuts. Then remove the nuts to slatted trays 3 by 6 feet and 3 to

6 inches deep. If the sunlight is intense the trays are placed in a shaded area, as under partially defoliated trees or light screens, where a current of air rapidly absorbs the excess water of the cleansing bath. If the rays of a declining sun are not too hot, the trays are spread on the ground (fig. 23) or on low horses in an open space. Prolonged exposure to a hot sun discolors the shells and sets oil free, which hastens rancidity when the nuts are afterwards stored. Should fall rains attend harvesting operations, place the trays in an artificial dryer where a current of moderately warm dry air may be passed over the nuts for a few hours.

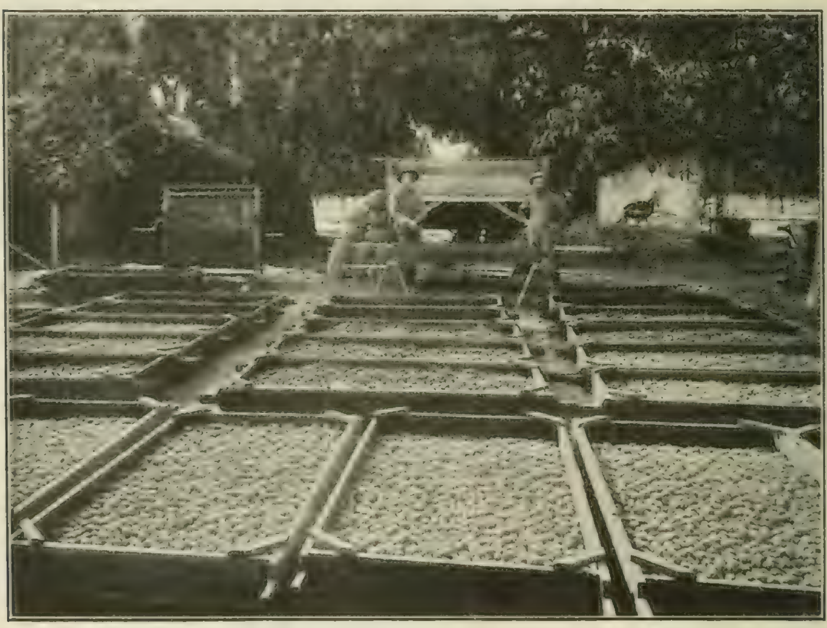

FIG. 23.—Screening and curing Persian walnuts at Anaheim, Cal.

CURING.

After being subjected to this preliminary drying process 10 or 12 hours in the case of the dryer and 3 to 5 days when exposed to the open air the trays of nuts are stacked in tiers 4 to 6 feet high for a week or 10 days, during which the nuts cure, or they may be placed in bins which permit free circulation of air, and should receive frequent turnings. After being fully cured they are graded by passing them over an oscillating inclined plane of wire screen or through an inclined cylinder of the same material, the slightly oblique mesh of which varies from 1 inch to 1$\frac{1}{64}$ inches square. With either apparatus the motion is slow, not more than 10 or 12 revolutions of the cylinder per minute or a corresponding number of oscillations of the plane.

HULLING.

Nuts which fail to free themselves from the shell at the time of falling from the tree (called "sticktights") are hulled by hand or put through a machine similar to a corn sheller (fig. 24). For a large quantity the machine method is quicker and cheaper than the hand method. Sticktights are usually due to want of water just prior to ripening. In dry seasons, where possible, a moderate application of water should be given the trees just before the hulls complete their growth. This treatment promotes plumpness of the hulls, which in consequence separate freely from the nuts.

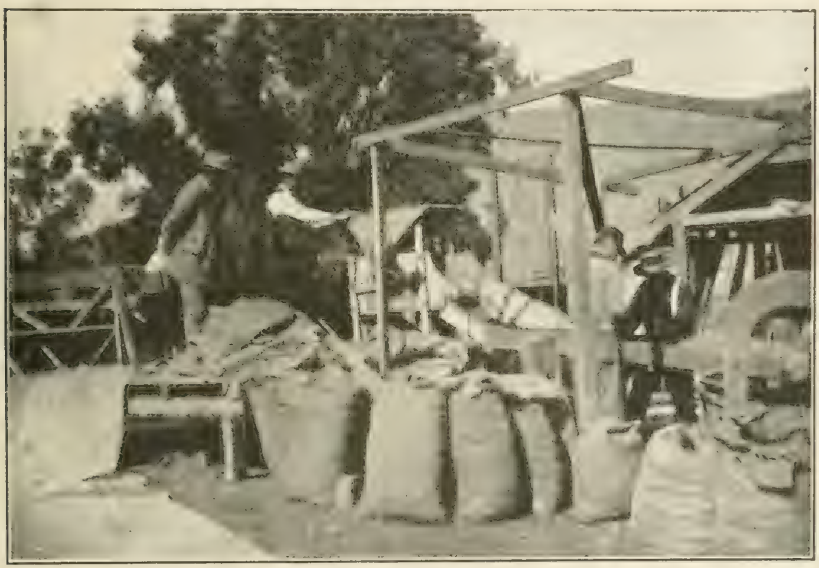

FIG. 24.—Hulling and sorting Persian walnuts near Santa Barbara, Cal. The nuts travel on endless belts directly from these operations to the drying trays.

ASSORTING.

Having passed the grader, which separates them into two grades, the nuts are next more or less closely hand picked. This assorting operation removes ill-formed, discolored, sunburned, and blighted nuts, and those with broken or perforated shells. In some instances, especially when the crop is wholly prepared at home, the hand picking is done while the nuts are passing over the grader. In the smaller processing plants assorting, generally performed according to a very liberal view of what constitutes standard grades, is done at any stage from grading to sacking as convenience suggests.

PROCESSING.

When commercially considered the southern California crop is usually processed, because under present demands for a bleached nut this operation offers the easiest, cheapest, and most expeditious means of handling the crop. Processing is responsible for a number of practices that are distinctly local, such as gathering the nuts at less frequent intervals than where processing is not practiced, and grading, bleaching, assorting, sacking, and selling in a specially equipped central plant on a basis determined by representatives of both grower and dealer. When the nuts are sufficiently cured at the orchard they are sacked and taken to the processing plant at or near the shipping point, where they are received and weighed, the grower being given a receipt for each lot as delivered.

To secure a uniform product the selling associations issue instructions to the growers covering details of the various harvesting operations. As the associations are composed of the growers as stockholders it amounts to the issuance by the growers of a set of rules for their own guidance in cooperative effort. The following instructions, issued by the Los Nietos and Ranchito Walnut Growers' Association, of Rivera, Cal., are representative of the action taken by such organizations in southern California:

ASSOCIATION INSTRUCTIONS.

Picking.—The nuts should be picked up as soon as practicable and not allowed to lie on the ground for any great length of time. The sun or fog will injure the meat of the nut or mar the appearance of the shell. Especially will this be the case where the outer hull adheres to the nut after it has fallen from the tree. The nuts should not be poled from the tree before fully ripe. A pole with an iron hook at one end will suffice to loosen the ripe nuts. Place the hook over the limb of the tree and suddenly jerk the pole; this will do the work.

Cleaning.—The nuts should not remain in the picking sacks for any length of time; if they do both the meat and shells are liable to become moldy, thereby injuring the quality and appearance of the nuts. The nuts should be thoroughly washed before being placed in the trays to dry and cure. The washing can best be done as the nuts are taken from the picking sacks and before the dirt adhering to the shell and the stain from the green hull dries. The cylinder washer will be found to be the best for washing the nuts. The time it takes to wash the nuts will depend on the condition of them, say from 10 to 20 minutes; use plenty of water.

Drying.—After the nuts are thoroughly cleaned they should be placed on trays in the sun, if not too warm, until thoroughly cured. The length of time will depend on the condition of the nuts and the weather. From 4 to 8 days will usually be sufficient. When the nuts are well cured the meats will be quite brittle; by this test you can tell when the nuts are properly cured. Care should be taken in drying soft-shell nuts. Too much sunshine will cause the nut to open; also the heat of the sun if very warm will start the oil in the meats, thereby causing the nut to become rancid. During foggy weather the nuts in the trays should be covered during the nighttime. This can easily be done by stacking the trays one upon the other and covering the top tray with burlap or any other material.

Blending plants.—While the blending plants are expected, so far as the appearance is concerned, to greatly improve our grade of walnuts, they will in nowise change the work of the grower in preparing the nuts for market, except sacking and delivering the crop to the walnut houses. It is especially recommended that the growers, in delivering their walnuts to the association, use the ordinary grain or barley sacks, that the sacks be filled uniformly and sewed, and that the name of the grower be stenciled on opposite sides of each sack to prevent loss of identity of the nuts before being placed in the blending plant; and also to insure the return of the delivering sacks to the owner.

Twine.—The association will issue to stockholders, at cost, from the Rivera Walnut House on specific dates skein twine for the use of stockholders for sewing the grain or delivering sacks.

All walnuts will be weighed when received from the grower and receipt for net weight given. Payment will be made in accordance with the by-laws of the association as soon as accounts can be made up after shipments of walnuts begin.

After receipt of the nuts at the processing plant they are conveyed to the first of a series of power-operated machines, where they are screened from any foreign substances gathered with the crop. After screening they are passed through the bleacher and then through the grader, though sometimes grading precedes bleaching. The nuts are next taken to assorters on an endless belt and carried to especially constructed aerating bins from which they are sacked and shipped.

GRADING.

From the screening machine the nuts pass into and lengthwise through a cylinder about 20 inches in diameter and 5 feet long, made of standard-size wire screen. This cylinder, called a grader, is set on an incline of about 15° and when rotated slowly allows the smaller nuts to pass through the mesh while the larger ones pass out at the lower end, separating the nuts, though not very accurately, into two grades called firsts and seconds.

To the writer there appears to be a weakness in the present method of marketing the crop. The product of the average orchard ought to have its firsts again separated into two grades if the crop is to obtain the returns to which it is entitled in comparison with other orchard crops. The average difference in price between firsts and seconds is about 20 per cent, somewhat less when prices are high and rather more when prices are low. Ordinarily there is as much difference between the sizes of the nuts marketed as firsts as between firsts and seconds, with the proportion reversed. The usual proportion between firsts and seconds is 9 to 1. On this basis, regrading of the firsts would put 9 per cent of the crop in a grade above the present first grade. This part of the crop on the present price scale would bring to the producer a net profit of nearly 2 per cent above what is now received, since there would be no additional cost in making the new grade. Should the walnut crop of the future be grown in large part upon grafted trees the above sizes and prices may not hold, since the fruit from grafted trees is much more uniform than from seedlings. Data of Franquette, Wiltz, and Concord nuts grown, respectively, in the Vrooman, Wiltz, and Hutchinson orchards of grafted trees show less than 5 per cent of seconds in the average crop and practically no variation in the size of the nuts rated as firsts. Should like results prevail in future orcharding, and leading authorities in all walnut districts are freely of that opinion, there may be little need to increase the number of grades in future except with reference to varieties. The trade requirements of the future will demand that grades be distinguished in other respects than by size alone. In addition to grading for size and its accompanying cracking percentage as at present, the interests of the industry make it evident that steps must soon be taken to insure grading on a more comprehensive basis. The nut trade suffers materially from insufficient discrimination in such points as the following: Form of nut; bleaching, sealing, uniformity in type, smoothness, regularity, color, and thickness of shell; cracking percentage; darkness, veining, and astringency of pellicle; lean or fat kernels; toughness, tenderness, crispness, flavor, and quality of flesh.

Were walnuts graded as closely as oranges, lemons, apples, and pears there would be at least one more grade, and probably two, which would bring the grower of extra-large or fancy nuts a corresponding advance in revenue, with added incentive toward raising the grade and quality of the output.

BLEACHING.

From the grading machine the nuts pass to the bleacher, a cylindrical piece of machinery similar in size to the grader but made of straight wire rods running lengthwise and held in position by encircling cross wires. After being sprayed with electrolyzed brine in passing through this machine, which, like the grader, is supported on an incline, the first-grade nuts are carried to a drying bin to remain for a few days, where air currents may circulate freely among them. Meantime the seconds separated by the grader are placed in sacks to await their course through the bleacher when the firsts have passed out. As the firsts and seconds leave the bleacher on endless belts for the finishing, aerating, or drying bins they are handpicked or assorted. The sorts, called culls or shells, are placed in separate bins and sold to confectioners or concerns that engage in the preparation of shelled meats for market.

Electrolytic bleaching is far superior to the chlorid of lime bath or sulphur fumes. Being simple in preparation, clean, and effective, it is less injurious to the nuts and more wholesome for the consumer, as little, if any, material gets into the nuts, and then only into those that are unsealed. The solution used is made by dissolving 5 pounds best-grade dairy salt in 100 gallons of water. This solution is placed in a battery jar and an electric current of 95 to

110 volts is applied. The variation in the strength of the current depends upon the purity of the salt. The cell containing the liquid is kept at a temperature of 90° to 95° F. It is applied to the nuts as a spray with a pressure of about 80 pounds.

As soon as the bleached nuts are dry they are sacked in the same manner as the wheat crop of the Pacific coast. In some instances, for convenience in identification while being handled, the sacks carrying the firsts have stamped upon them lengthwise a distinct colored band or broad stripe.

A perceptible opposition to bleaching is manifest on the part of those consumers familiar with both the bleached and the unbleached product. Undoubtedly some of this unfavorable criticism in the past has been deserved, since it is well known that the old process of dipping in chlorid of lime permitted more or less of the solution to enter nuts not well sealed, rendering them disagreeable to the taste. This objection is avoided by the bleaching process already described, known as the salt bath, in which the solution rarely enters the shell, and if it does, nothing more than a mild salty taste is detected. Another objection to bleaching, which further investigation may overcome, is that it prevents the proper curing of the kernel through the destruction of the enzymes or other agents that develop in the unbleached nut.

While the bacteriologist is settling this question perhaps we may ascertain how to harvest, cure, and market the crop without the necessity of bleaching. At present a limited quantity of unbleached nuts are so marketed and, so far as known, bring prices equally high. The public will soon learn to accept the natural-colored nut, provided it is clean, unstained, and sold at the same price. The problem involves change in harvesting practices, and doubt arises as to the possibility of producing as uniformly clean and bright an output as is now offered by electrolytic bleaching without materially increasing the cost of production. In the face of what promises to be a growing sentiment against bleaching on the part of consumers who require a high-grade or fancy nut, the grower is likely to order his product to meet the consumer's demand.

STORING.

In the main, the keeping qualities of walnuts are excellent, but in order to insure the best results in storage they should be kept in a cool dry room constructed to exclude insects; otherwise wormy nuts will result from prolonged storage. Exposed to damp, nuts soon mold or decay, and even when dry the nuts will become rancid if kept too long. Dr. Thomas A. Knight, writing in 1811, said:

> I have subsequently found that both chestnuts and walnuts may be preserved through the whole winter nearly in the state they came from the trees by cover-

ing them with earth (as potatoes are usually covered in the gardens of cottagers) and mingling a sufficient quantity of moderately dry mold with the nuts to occupy the space between them.[1]

Such a practice might not be amiss for the orchardist keeping his own crop, but would be impracticable when the market demands a clean, bright, or bleached product. To meet this demand there appears to be only one course to follow, and that is to subject the crop to cold storage after being fully cured. A temperature such as is maintained for the storage of apples ought to be suitable for walnuts, though no reports of experiments upon this point have been made.

With walnuts that are to be stored for an extended period care must be exercised in the selection of thoroughly sealed nuts unless they are placed in air-tight chambers and kept cold. In ordinary storage chambers weakly sealed nuts are subject to serious damage by worms and weevils. Experiments now being made in the storage of pecans by C. A. Reed, of the Department of Agriculture, promise excellent results. Kernels cracked in 1911 were placed in vacuum-sealed glass jars, and on being opened in March, 1912 were found as crisp and fresh as when cracked. During this period the jars were stored in an office room at ordinary temperature. While storing walnuts commercially is somewhat different from this treatment of pecans in that the larger number of stored nuts will be unshelled, there appears to be no reason why the method should not give as good results with walnuts as with pecans.

WALNUT GROWING AS A BUSINESS.

PRODUCTION AND CONSUMPTION.

During the years of the past decade the quantity of walnuts marketed in the United States has been approximately as follows:[2]

TABLE III.—*Persian walnuts marketed in the United States, 1902–1911.*

Year.	Domestic unshelled.	Imported.		Price for the home product.[3]	Year.	Domestic unshelled.	Imported.		Price for the home product.[3]
		Unshelled.	Shelled.				Unshelled.	Shelled.	
	Pounds.	*Pounds.*	*Pounds.*	*Cents.*		*Pounds.*	*Pounds.*	*Pounds.*	*Cents.*
1902..	13,800,000	10,394,048	2,594,288	9½	1907..	15,096,887	23,036,646	7,199,988	11
1903..	17,400,000	8,936,439	3,035,970	10	1908..	14,674,543	21,427,853	7,098,958	15
1904..	12,628,248	19,454,012	3,579,941	12½	1909..	20,286,769	17,432,885	8,781,909	12½
1905..	15,175,994	16,312,139	4,178,010	11	1910..	18,695,686	23,269,974	10,960,988	11½
1906..	12,776,136	15,029,724	4,948,175	13	1911..	19,388,776	21,146,116	11,244,055	15

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[1] Transactions of the Horticultural Society of London, ser. 1, vol. 1, 1820, p. 247.

[2] Reports for the years 1902 and 1903 by the Southern California Walnut Growers' Association. The data for 1904 to 1911, inclusive, are taken from compilations made by F. A. Hazzard from the record of shipments made from points in southern California.

[3] Net at the association's headquarters, less approximately 7½ per cent commissions.

According to the French ratio the shelled product is equivalent to slightly more than 40 per cent of the whole nut. The estimate of the total American consumption here given is based on this ratio for the imported product. It thus appears that the people of the United States during 1910 consumed approximately 35,000 tons of walnuts, more than 25,000 tons of which were imported. About five-sevenths of the importations came from France, while the larger part of the other two-sevenths came (in the order of the quantities imported) from Italy, Turkey in Asia, Austria-Hungary, the United Kingdom, and the Chinese Empire. Practically all of the home-grown commercial crop was produced in California, though Oregon sold a few carloads. A few thousand pounds were marketed from small orchards and individual garden, lawn, or roadside trees in Washington, New York, Pennsylvania, Maryland, New Jersey, and Delaware, while scattered trees in Michigan, Ohio, Virginia, West Virginia, Texas, and Georgia yielded a few hundred pounds for home use.

A great opportunity evidently exists for extending the area of production of the home crop. The present activity to secure hardier disease-resistant varieties of high quality and to improve the methods of propagation is evidence of the effort to take advantage of this opportunity. The interest of the public also suggests extended trial of the more promising hardy varieties over a wide range of such territory as appears at all suited to the successful cultivation of this tree.

YIELD.

There are authentic records of individual trees in Europe yielding as much as 2,000 pounds, while the largest yield recorded for an American tree is 712 pounds. This tree, known as the Payne tree, located at Campbell, Cal., is of magnificent proportions. It originated by the planting of a California black walnut in 1871. In 1896 the tree was top-worked with wood of the Santa Rosa Persian walnut. Though originally planted in a row with others, it grew so rapidly from the start that it soon overshadowed the others and has practically become an isolated tree, except for a white walnut, or butternut, some 60 or more feet away. Growing upon a deep fertile soil and fed by the wash of the barnyard, the crop of this tree is not a fair criterion by which to approximate the yield of a commercial orchard, though it has often served that purpose for the promoter of walnut orchards sold on the installment plan. In favorable seasons, with orchards growing upon deep rich soils well supplied with moisture, it is not unusual to harvest from an acre of seedling trees, 20 years of age, a ton or more of marketable nuts, but a conservative basis for investment is 1,000 to 1,200 pounds. The following statement from the books of a successful grower in the Rivera section of California exhibits the results of an average orchard well managed. He had trees covering 8 acres 27 years old, 15 acres 16 years old, 12 acres 12 years old, and 7 acres 10 years old, which produced during 1910 nuts to the gross value of $5,200, or an average of $123.85 per acre. His approximate yield per acre was 825 pounds for 16-year-old trees. Statements of a yearly product considerably higher than these figures are frequently published, but careful inquiry among scores of successful growers in Oregon and California does not confirm them for average yields, one year with another, under varying conditions of soil and climate. It must be remembered, however, that statistics of yield from commercial orchards are taken at present almost exclusively from orchards of seedling trees, which are unquestionably less prolific than grafted trees of selected parentage. Though no authentic records are available, it is asserted that grafted trees of productive varieties, besides coming into bearing earlier, yield 20 per cent more nuts than average seedling trees. This estimate appears conservative when we consider that grafted trees may also be immune to blight. Further, the product of grafted trees brings a higher price upon the market. In the prices quoted for the output of the Southern California Walnut Growers' Association for 1910 nuts from grafted trees were favored by a $16\frac{2}{3}$ per cent advance over the general seedling crop. These two items are of weight when the factors in profitable orcharding are under consideration.

TABLE IV.—*Statement showing number of farms reporting Persian walnuts, trees of bearing and nonbearing age, quantity produced, and value, census of 1910.*[1]

State.[2]	Number of trees Apr. 15, 1910.				Products of 1909.	
	Bearing age.		Nonbearing age.		Quantity.	Value.
	Farms reporting.	Trees.	Farms reporting.	Trees.		
					Pounds.	
Alabama*	983	3,022	1,164	4,180	43,673	$3,557
Arizona*	23	103	62	324	1,000	161
Arkansas*	182	1,284	182	1,260	15,436	1,384
California	7,357	853,237	6,554	546,804	21,432,266	2,247,193
Colorado	6	39	7	80	25	3
Delaware	6	15	7	15	222	44
Florida*	301	786	327	1,489	28,575	2,018
Georgia*	1,020	3,433	984	6,996	56,585	4,161
Idaho	52	407	74	1,013	633	79
Illinois	87	772	12	1,045	3,497	331
Iowa	1	200	....	....	....	....
Kentucky*	106	1,227	46	1,193	35,825	1,499
Louisiana*	411	1,228	398	3,390	15,173	1,446
Maryland	754	2,068	444	1,758	6,916	745
Minnesota	1	1	2	7	50	5

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[1] The census tabulation shows no production of Persian walnuts in Connecticut, District of Columbia, Indiana, Kansas, Maine, Massachusetts, Michigan, Montana, Nebraska, New Hampshire, North Dakota, South Dakota, Vermont, and Wisconsin; but herbarium specimens and correspondence show that nuts of fair quality are grown in favorable sections of Connecticut, Michigan, and the District of Columbia.

[2] Observations and correspondence indicate that the enumerators in States marked with an asterisk (*) failed to distinguish between the product of the American black, the Japanese, and the Persian walnut. Students of horticultural conditions in these States, men of high scientific, professional, and business standing, assert that it is not possible to obtain such figures except by indiscriminate use of the term walnut.

TABLE IV.—*Statement showing number of farms reporting Persian walnuts, trees of bearing and nonbearing age, quantity produced, etc.*—Continued.

State.	Number of trees Apr. 15, 1910.				Products of 1909.	
	Bearing age.		Nonbearing age.		Quantity.	Value.
	Farms reporting.	Trees.	Farms reporting.	Trees.		
					Pounds.	
Mississippi *	893	2,705	1,239	5,513	66,492	$6,949
Missouri *	86	1,214	48	909	5,791	618
Nevada	8	39	11	148	200	20
New Jersey	170	429	138	1,360	2,798	302
New Mexico	15	250	123	1,641	715	91
New York	81	456	28	139	9,346	858
North Carolina *	563	2,125	509	1,731	73,303	3,686
Ohio	71	599	30	220	2,461	154
Oklahoma *	252	6,889	198	5,962	6,700	489
Oregon	1,134	9,526	4,300	177,004	79,000	8,288
Pennsylvania	53	198	68	142	4,523	516
Rhode Island	1	4	1	1		
South Carolina *	473	1,373	526	1,834	28,160	2,583
Tennessee *	96	437	49	137	4,157	295
Texas *	626	9,685	704	13,015	40,658	3,703
Utah	53	292	42	481	5,985	533
Virginia *	371	3,540	194	1,642	22,512	1,231
Washington	509	3,651	1,461	23,406	16,450	2,241
West Virginia *	121	3,035	59	1,481	17,337	2,153
Wyoming	1	1				

FOOD VALUE.

According to Prof. M. E. Jaffa, of the University of California, who has made extended analyses of the composition of nuts and other foods, walnuts, inclusive of the shells, are estimated to comprise a waste of about 58.8 per cent of the uncracked nuts as usually found upon the market. They have a value as represented by the heat units (calories) they furnish, pound for pound, comparable with other food products, as shown in Table V.[1]

TABLE V.—*Average fuel value of walnuts as compared to other food products.*

Food product.	Average price per pound, 1910.	Refuse.	Fuel value of edible portion.	
			Calories per pound.	Calories for 1 cent.
		Per cent.		
Round steak	$0.15		950	63
Wheat flour	.04		1,650	412
White bread	.05		1,215	243
Dried beans	.045		1,605	356
Raisins	.10	10	1,605	145
Walnuts	.25	58.8	3,075	51

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[1] Yearbook, U. S. Dept. of Agriculture, for 1906, p. 299.

Considering the comparative value of walnuts and other food products, it is evident that the walnut can not be rated according to present market prices as an article of ordinary diet. Before the Persian walnut can become an article of daily consumption the crop must be produced in much larger quantities, necessitating extensive additional acreage. Relatively little high-class land suitable for the Persian walnut is available in southern California, except at very high cost. This region offers several thousand acres suitable for the production of this crop, provided care is used in the selection of site and varieties, though the fact is that much of this acreage will probably be planted to crops yielding earlier and more profitable returns. It will be necessary to enter other districts if the crop is to keep pace with the increased consumption, and preliminary tests warrant the statement that the crop can be successfully and profitably grown in other sections.

In connection with the topic of food value, it may be well to call attention to one or two features of the American-grown nut that merit attention, especially by those engaged in its improvement. The connoisseur of nuts is persistent in his assertion that the kernels of the French varieties when grown in the United States are much more starchy than when grown in France. He also asserts that many of our best American-grown nuts are more or less bitter and astringent.

These criticisms are not made in a spirit of disparagement but of helpful suggestion. It is assumed that if our nuciculturists have accepted ideals placed before them effort will be made to embody these ideals in American seedlings, insuring sooner or later a nut vastly improved in those properties that make a product of the highest quality.

At present the American public does not discriminate between the different varieties, types, or qualities of walnuts. When the home product shall equal or excel home consumption more discrimination will be shown. Already American growers are awake to the need of arousing the public to an appreciation of the fact that the first-grade home product is not to be classed with the foreign varieties generally used for replacement purposes.

It is opportune to have this matter of American quality brought to the attention just as we are beginning a notable advance in the improvement and culture of this nut, and to the criticism and demand of the connoisseur we shall be indebted for stimulation in the development of new and better varieties.

INVESTMENT AND OPERATION.

Though seasonal variations bring more or less change in the tillage operations of a walnut orchard, the following figures recording the experience of growers throughout California, Oregon, and Washington may be considered a conservative estimate of the investment and expenses necessary to produce and market an average crop of walnuts. The average crop one year with another from trees 15 to 25 years of age is 1,000 to 1,200 pounds per acre.

In the States named first-class land suitable for walnut growing cleared and ready for planting costs $150 to $1,000 per acre according to location. In outlying sections, especially in northern California, Oregon, and Washington, land may be bought for $100 per acre. In sections where the walnut finds a congenial home higher prices prevail. Grafted trees cost $1 to $1.50 each; preparation of the soil and planting the trees, $4 to $6 per acre; pruning, 75 cents annually per acre as an average for the first 10 years; two or three times that amount for the next 10-year period, and slightly more afterwards; tillage, $12 to $20 per year if no intercrops are grown; irrigation, $2 to $6, according to character of soil, season, age, and bearing of the trees; fertilizers and cover crops (for nitrogen and humus) $2.50 to $5; superphosphate, $8 to $10; harvesting, $20 to $30 per ton; charges for processing, $10 per ton; commission on sales, 7½ per cent. The average price of the product during the past 10 years has been 12½ cents per pound f. o. b. at point of shipment on the Pacific coast.

NOTE.—Since the second paragraph on page 20 was written, the severe winter of 1911–12 wrought such damage to all Persian walnut trees on their own roots that it is necessary to change the tenor of the statements therein. Throughout eastern Pennsylvania and in the District of Columbia many old trees were killed outright or so severely injured that they will die within a year or two. In those instances, however, where the writer has made a personal examination the trees were found to be growing under the unfavorable conditions usually prevailing in the walled-up back yards of cities. A few trees growing under the more favorable environments surrounding country homes in this same territory have been reported as suffering severe injury from the low temperatures, —20° to —33° F., of January, 1912.

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PLATES.

DESCRIPTION OF PLATES.[1]

Plate I. (*Frontispiece.*) A well-kept Persian walnut orchard in California, illustrating the thorough tillage that may be readily maintained among low-headed trees.

Plate II. Varieties of walnuts—I. The principal species and hybrids now attracting attention in this country. Upper row, from left to right: Royal (*Juglans nigra* × *Juglans californica*), Paradox (*Juglans regia* × *Juglans californica*), Ignotum (*Juglans regia* × *Juglans cinerea*), Butternut, or white walnut (*Juglans cinerea*). Middle row: Siebolds Japan walnut (*Juglans sieboldiana*), Chinese walnut (*Juglans regia sinensis*). Heart-shaped Japan walnut (*Juglans cordiformis*). Lower row: American black walnut (*Juglans nigra*); (*Juglans californica*), northern form, California black walnut, southern form; rock or Texas walnut (*Juglans rupestris*), flat form; rock or Texas walnut (*Juglans rupestris*), long form; rock or Texas walnut (*Juglans rupestris minor*), Arizona form.

Plate III. Varieties of walnuts—II. Top row, left to right: Bijou, Klondike, Honeydew. Bottom row: Hall, Payou, Meylan.

Plate IV. Varieties of walnuts—III. Upper row, left to right: Grenoble, Santa Rosa, Persian, Sorrento. Lower row: Santa Barbara, Santa. Barbara (Williams form), Santa Barbara (More form), Hardshell.

Plate V. Varieties of walnuts—IV. Upper row, left to right: Mayette, Concord, Ward, Chelan. Lower row: Neff, Franquette, Parisienne, Nebo.

Plate VI. Varieties of walnuts—V. Upper row, left to right: Two French seedlings (varieties on the same tree), Fertile, Chaberte, Cumberland. Lower row: Placentia, Mayquette, Kaghazi, Chase.

Plate VII. Varieties of walnuts—VI. Upper row, left to right: Ford, Eureka, Rush, Prince. Lower row: Holden, Treyve, Payne, Prolific.

Plate VIII. Varieties of walnuts—VII, Upper row, left to right: Alpine, Journeay, Mount, Cluster. Lower row: Vourey, Hubbard, Serotina, Late Fertile, Cutleaf.

Plate IX. Varieties of walnuts—VIII. Upper row, left to right: Hales, Keesling, Milbank, Lane. Lower row: Hays, Lalande, Derby, Lea, Sinclair.

Plate X. Varieties of walnuts—IX. Upper row, left to right: Chase 2, Chase 1, Kaghazi, Mayquette. Lower row: Pomeroy, Pomeroy seedling, Chaberte, Fertile, Dean.

Plate XI. Varieties of walnuts—X. Upper row, left to right: Franmay, Prince, Wiltz, Glady. Lower row: Ellwood, Cumberland, Placentia, Persian (round).

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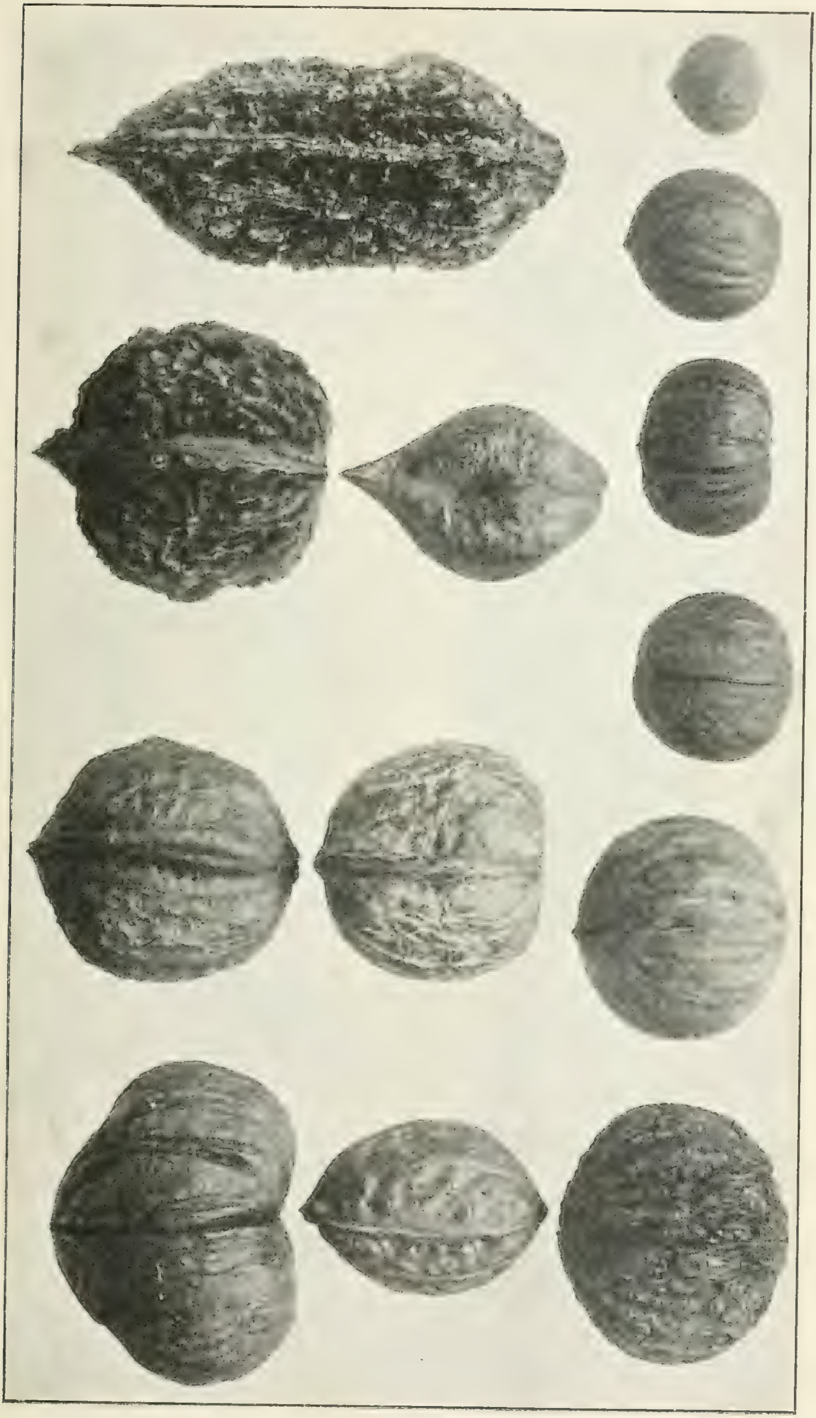
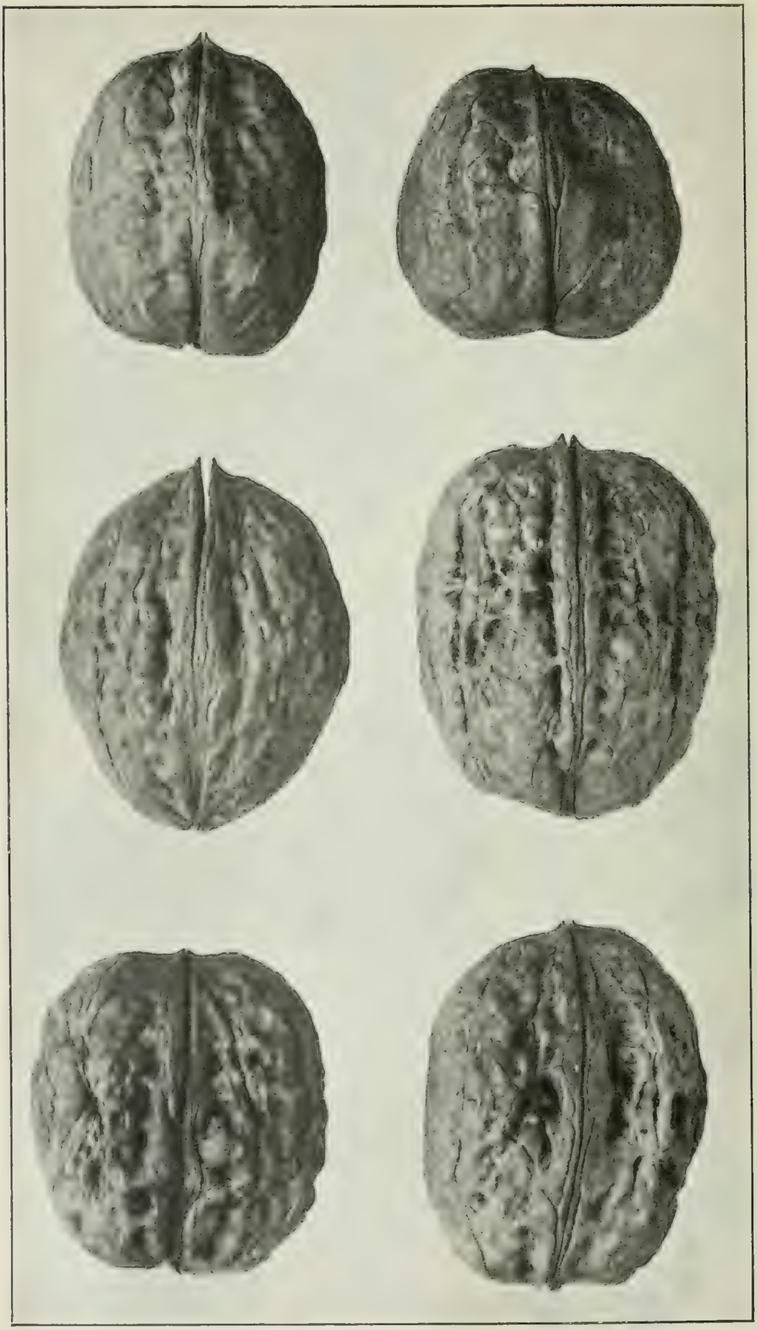
[1] The bottom row in each instance is the lengthwise row next the plate legend.



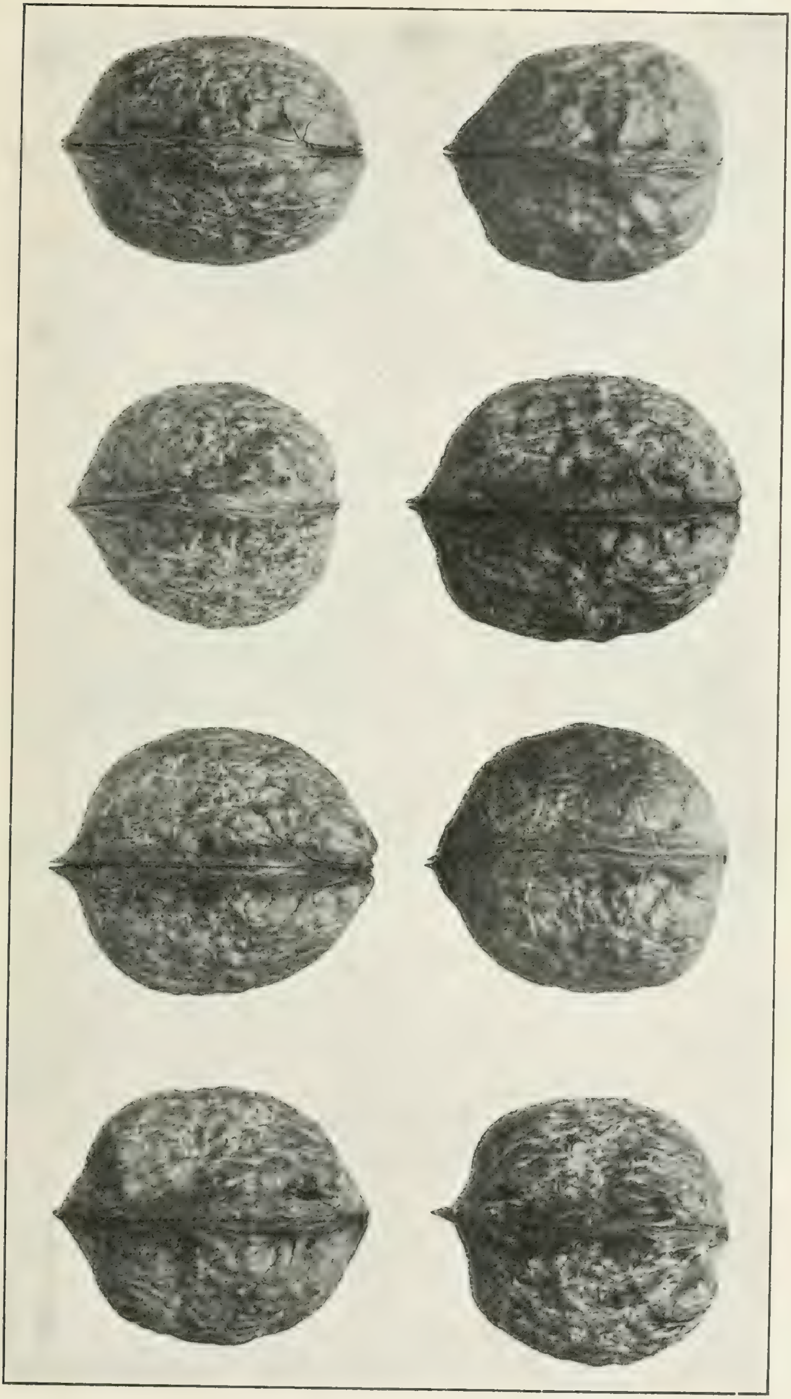
VARIETIES OF WALNUTS—I.

PLATE III.



VARIETIES OF WALNUTS—II.

PLATE IV.



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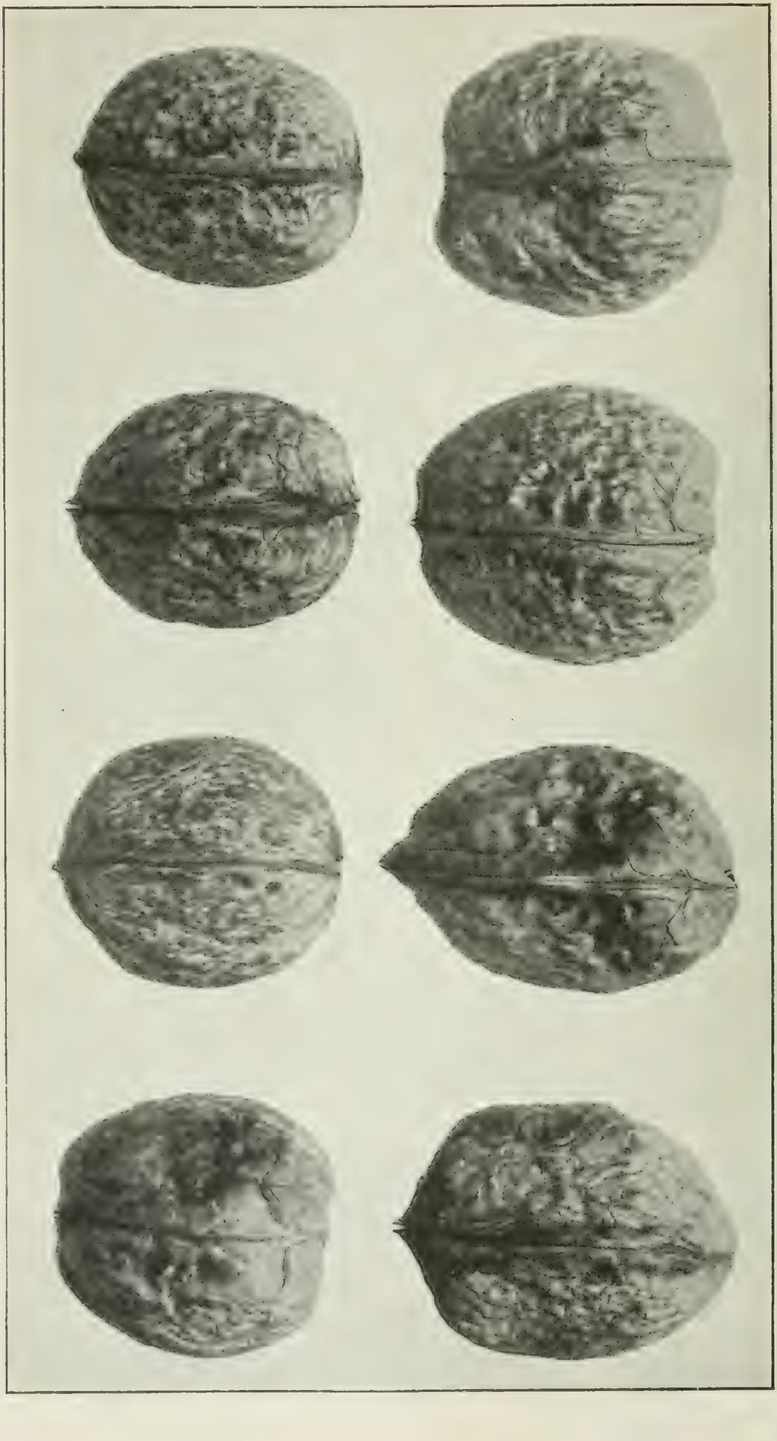
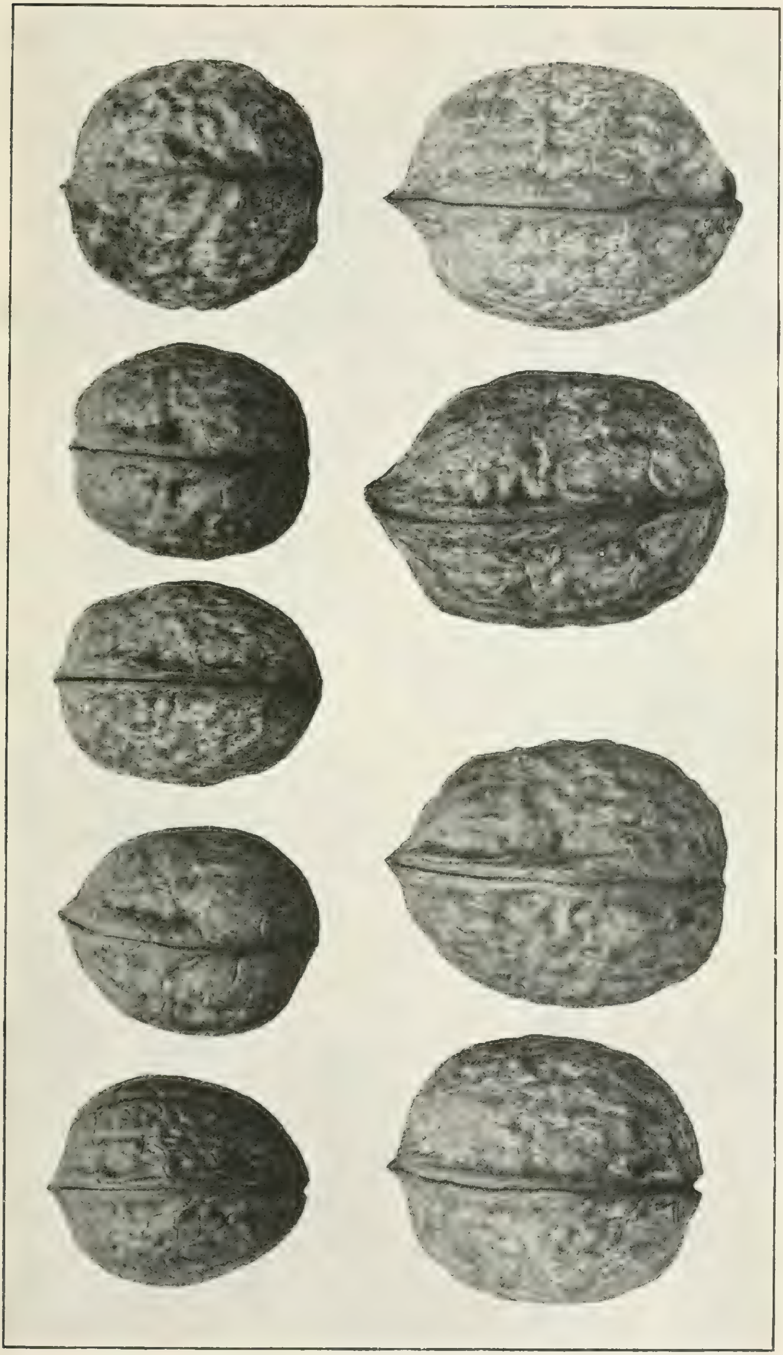


VARIETIES OF WALNUTS—IV.

PLATE VI.



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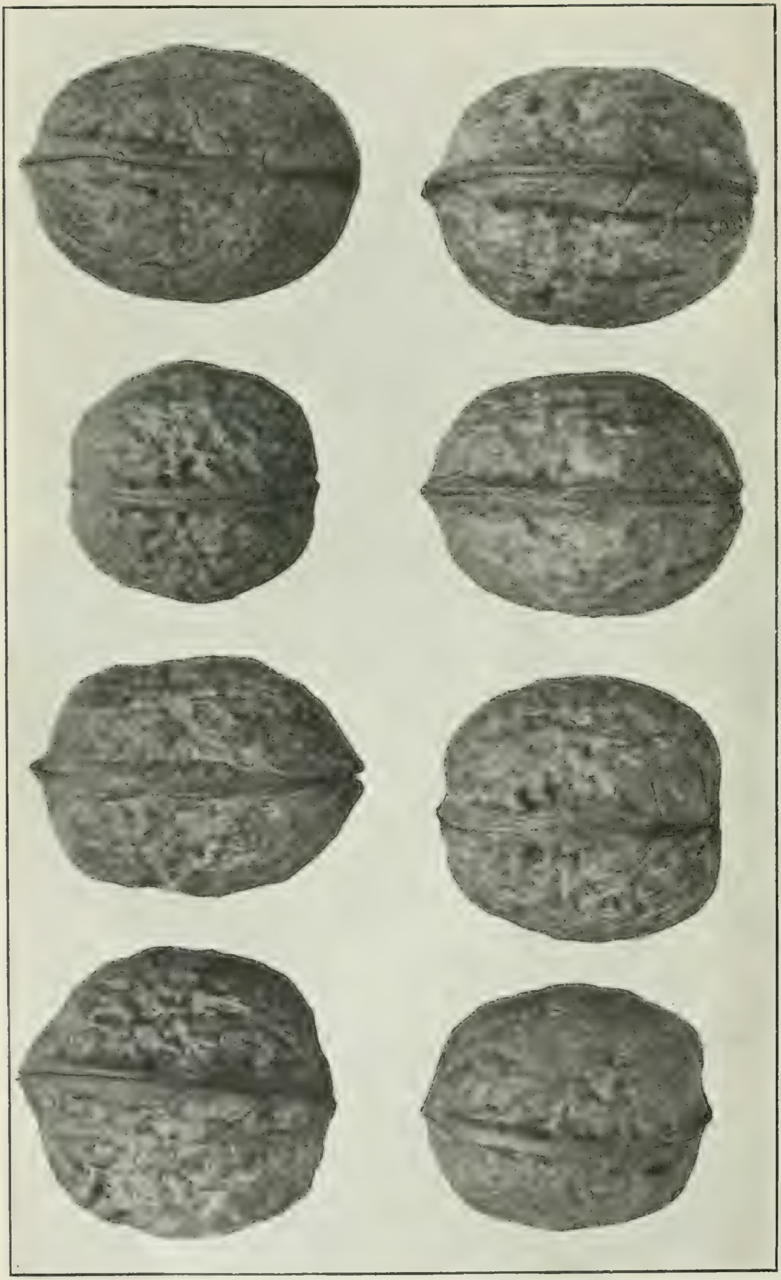
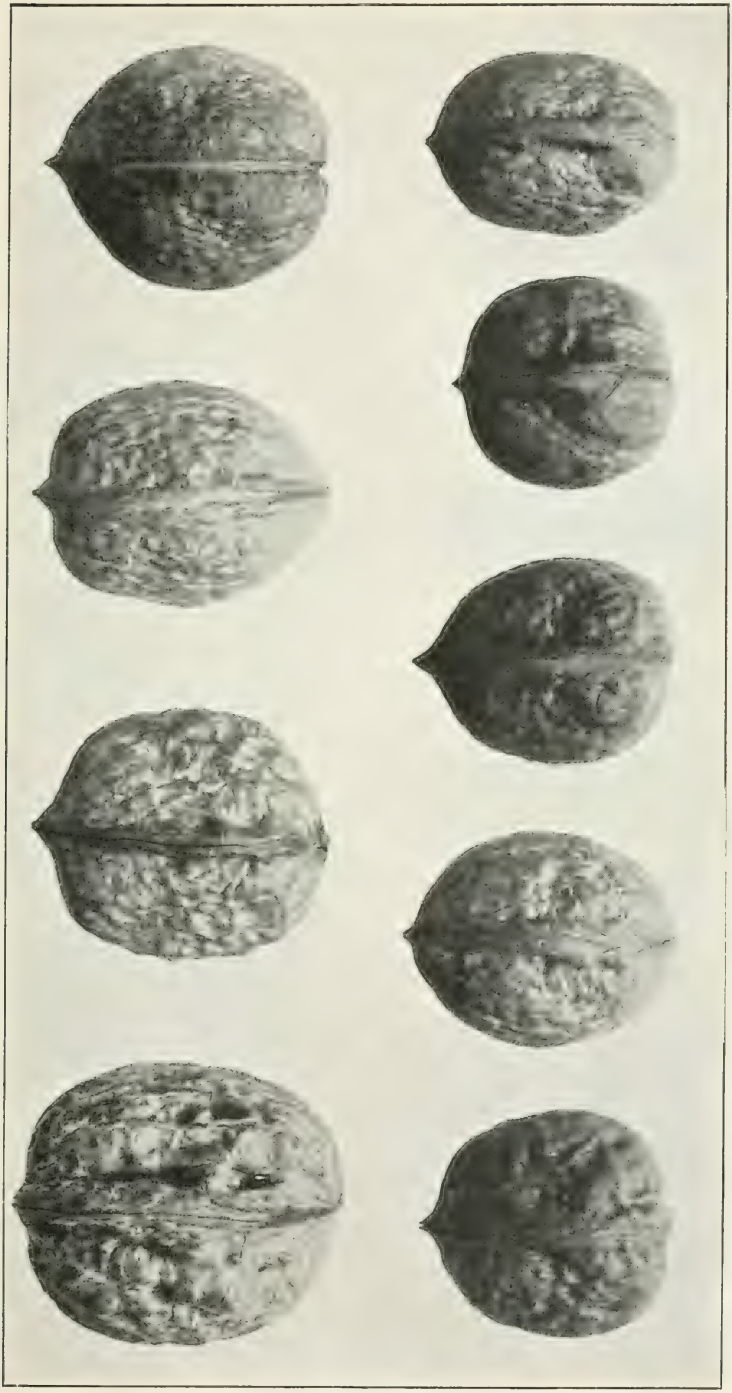
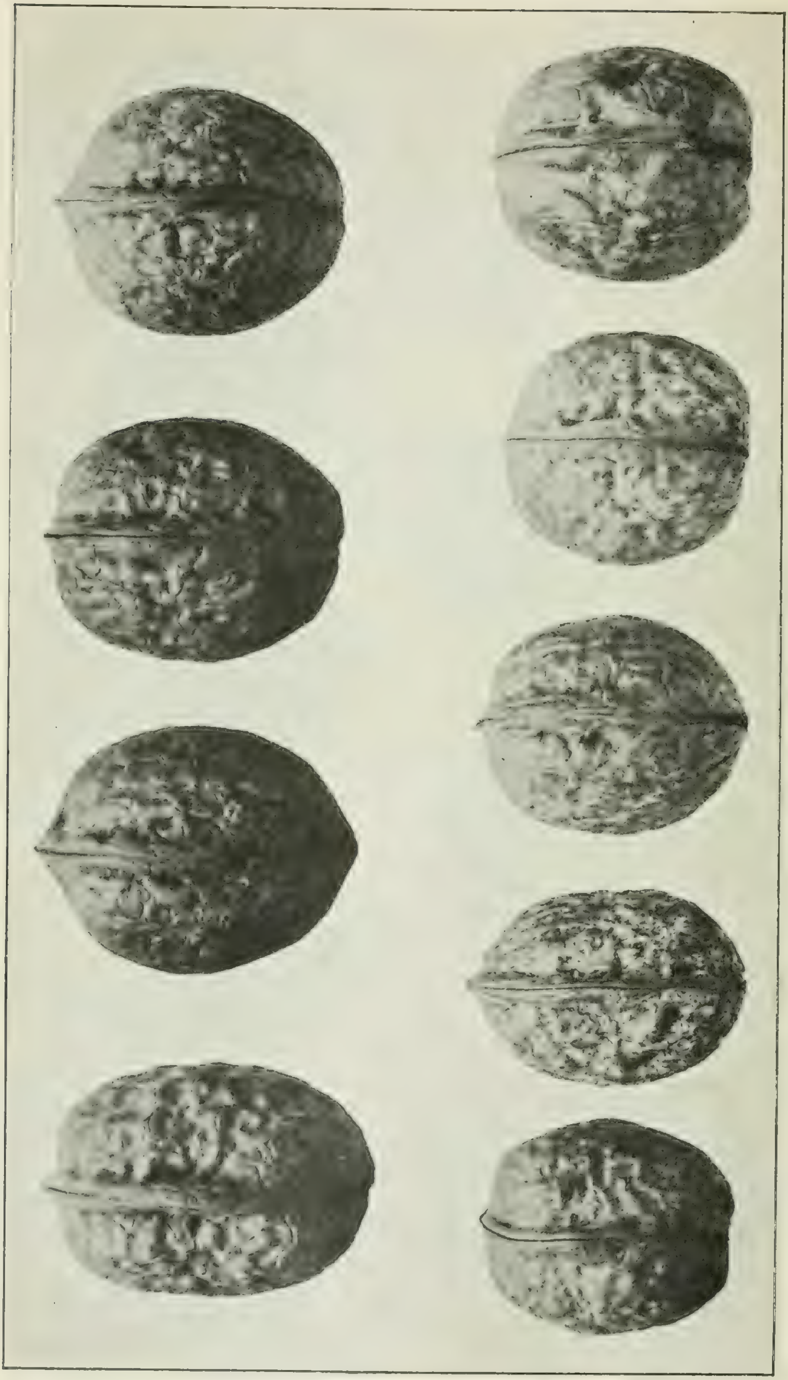


VARIETIES OF WALNUTS—VI.



VARIETIES OF WALNUTS—VII.



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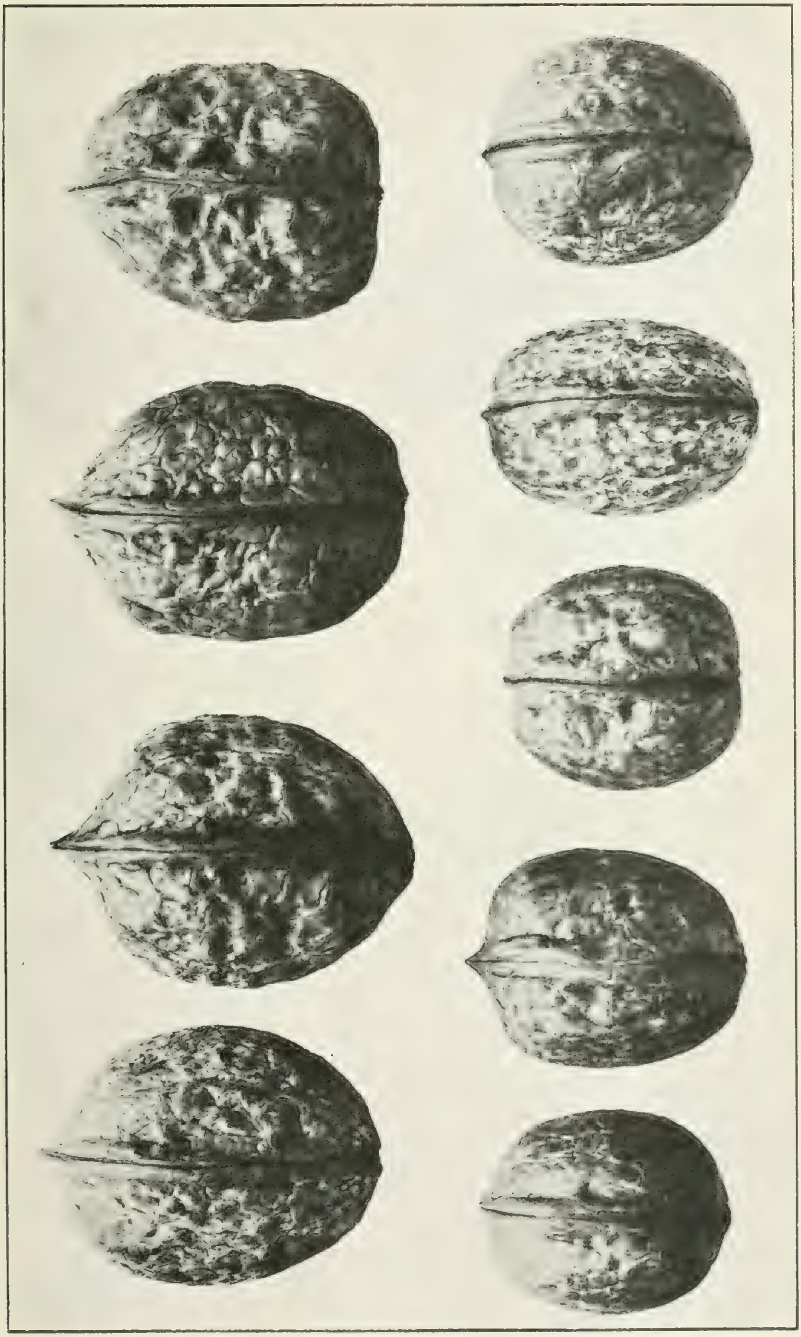
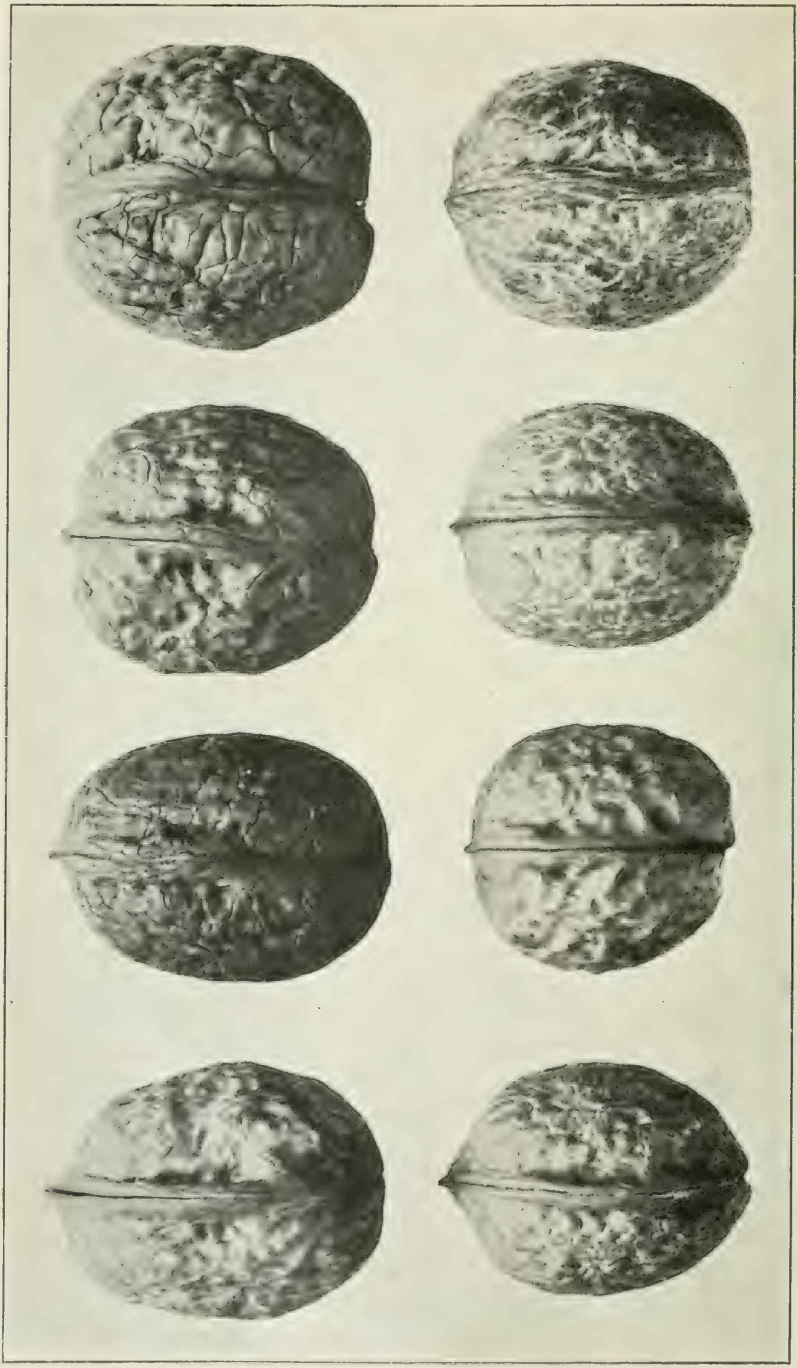


VARIETIES OF WALNUTS—IX.



VARIETIES OF WALNUTS—X.

U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 255.
B. T. GALLOWAY, *Chief of Bureau.*

THE STRUCTURE AND DEVELOPMENT OF CROWN GALL:

A PLANT CANCER.

BY

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AND

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Scientific Assistants.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 9, 1912.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 255 of the special series of this bureau the accompanying technical paper by Dr. Erwin F. Smith, Miss Nellie A. Brown, and Miss Lucia McCulloch, entitled "The Structure and Development of Crown Gall: A Plant Cancer."

This paper is the result of many months of critical study of hundreds of serial sections prepared on the microtome; and so far as relates to the photographic demonstration of the presence of the causal organism within the proliferating cells, to several years of laborious and discouraging experimentation with a variety of fixing agents and stains. Only recently has it been possible to demonstrate clearly by means of the microscope the presence of the parasitic organism within the cells, although the authors have known for more than five years that this organism *must be* located within the cells, because in galls shown by the agar poured-plate method to contain the bacteria, no granules of any sort occur between the cells or in the lumen of the vessels.

Had Dr. Smith's researches on crown gall been confined only to morphology (excluding parasitology) it would be reasonable for him to make precisely the same statement now commonly made by research workers in cancer, viz, "The cell itself is the only parasite. That fully explains all the observed phenomena." But, adding the bacteriological evidence, we see for the first time clearly that while it is the rapidly proliferating cancer cells that do the mischief they are impelled to behave in this way only because they are under the stimulus of a foreign organism which does not destroy them, but irritates them to rapid division and passes over into certain of the daughter cells to repeat the process indefinitely. This, it can not be denied, is a discovery of the first magnitude in pathology.

A preliminary announcement of certain of these new discoveries was made a year ago, to wit, the existence of a tumor strand and of stem structure in secondary tumors. The paper herewith submitted furnishes the promised photomicrographic proofs in support of those statements.

The interest which the preliminary statements have awakened, not only among plant pathologists, but also among medical men in all parts of the world, and the manifestly important bearing of these researches on the origin of malignant human and animal tumors, make it desirable to publish the investigations in full. It is recommended, therefore, that the paper be published as submitted, with all of its illustrations, and at as early a date as possible. The illustrations submitted are the essential part of the paper, the text, for the most part, being only a running commentary.

Respectfully,

B. T. GALLOWAY, *Chief of Bureau.*

HON. JAMES WILSON,
Secretary of Agriculture.

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THE STRUCTURE AND DEVELOPMENT OF CROWN GALL: A PLANT CANCER.

INTRODUCTION.

This is a bulletin on the histology of crown gall. For five years the senior writer has been hammering away at the idea that crown gall of plants resembles malignant human tumors and can be made to throw a flood of light on the origin of the latter, which is still shrouded in obscurity and believed by the majority of pathologists to be of nonparasitic origin (vide Bashford, Reports of Imp. Cancer Research Fund).

A year ago the discovery of a tumor strand and of a stem structure in secondary tumors in leaves gave a strong impetus to this view. In the interim this contention has been expressed publicly several times (vide Science, Feb. 2, 1912, and Centralb. f. Bakt. 2te Abt., 1912). The bulletin here offered is in the nature of supporting evidence.

This view received only a cool welcome at first, very likely through more or less inapt presentation, but recently it has received respectful attention. In October, 1910 (Int. Cancer Congress, Paris), Jensen, of Copenhagen, expressed similar views respecting a tumor on the sugar beet.

In the meanwhile, on the animal side several publications of prime importance, all within the year, or very nearly, have tended strongly to unsettle the crystallizing belief in the nonparasitic origin of cancer. These have been as follows:

(1) The announcement by Peyton Rous (Jan. 21, 1911) that a chicken sarcoma is inoculable in the absence of living chicken cells, i. e., with fluid freed from the ground sarcoma by centrifuging, and also by filtration through moderately coarse Berkefeld bougies. Fine bougies will not serve. Later, in the Journal of Experimental Medicine, he furnished what seem ample proofs of this contention. Very recently he has shown that tumor material dried for six months is still infectious. (April 4, 1912, An. Meeting Am. Asso. for Cancer Research.)

(2) The discovery by von Dungern that when a round-celled sarcoma of the dog was grafted on the fox *only fox cells grew.* (Muenchner Med. Wochenschrift, Jan. 30, 1912, p. 238.)

(3) The recent statements by Wassermann, Keyser and Wassermann, that cancer cells of mice (both carcinoma and sarcoma) have a selective affinity for salts of selenium when these are passed into the blood stream in combination with eosine, thus showing that the contents of tumor cells is chemically distinct from that of normal cells. (Deutsche Med. Wochenschrift, No. 51, Dec. 21, 1911, p. 2389).

CROWN GALL A NEOPLASM.

That we have in crown gall peculiarities of neoplastic growth which remove it from all ordinary plant diseases and place it in the category of the true tumors (atypical blastomas) is the burden of this bulletin.

The phenomena of growth in this disease are in the highest degree surprising and are quite unlike anything hitherto known in plant pathology. It is believed for reasons that will become evident further on that for comparable phenomena we must turn to animal pathology, and particularly to that part of it which deals with malignant tumors. Among the latter only do we find growths which appear to be identical. In other words, the contention of this bulletin is that crown galls are to all intents and purposes cancers.

The histological evidence on which this statement is based is presented in the following pages in the form of photomicrographs, only so much text being appended as shall serve to make the sun pictures intelligible. Accompanying these photomicrographs are photographs of the inoculated plants, introduced to show relation of parts. It is believed that more can be learned as to the nature of this disease from an inspection of these pictures than from any number of pages of text, because texts and even drawings are liable to be colored more or less by the beliefs of the writer, whereas the camera reproduces only what is present, albeit sometimes rather imperfectly.

The morphological likeness of crown gall to malignant animal tumors consists in—

(1) A peripheral growth of tumor cells out of preexisting tumor cells, with absence of any capsule or well-defined limit to growth. The growth is injurious and extraphysiological, and, exactly as in human cancer, the cell itself is the only visible parasite.[1]

---

[1] "We can say, then, that cancer is not due to a specific parasite or parasites, but, on the other hand, we can say that cancer cells themselves act as parasites. This view will explain all the phenomena of cancer."—*Dr. Charles Powell White.*

"The whole basis, objective and theoretical, of the cancer parasite has been traversed again and again, with the uniform conclusion of those who finish the journey that the cancer parasite is the cancer cell."—*Dr. James Ewing, in his Cancer Problems.*

"*Cancer bodies.*—There exists, in fact, a very remarkable series of localized degenerative changes in cancer cells that have been the cause of active controversy for now close upon 20 years; nor can it be said that the controversy is as yet at an end, although the main body of pathologists of all countries is now of the opinion that these appearances are degenerative and not parasitic. For some years, however, the parasitic theory of cancer had active and enthusiastic supporters."—*Adami, Principles of Pathology, vol. 1.*

(2) The existence of a well-developed supporting stroma.

(3) The formation of tumor strands which extend from the primary tumor in various directions.

(4) The development on these tumor strands of secondary tumors which have the structure of the primary tumor even when they are located in other organs.

(5) The existence of giant cells, i. e., cells which contain several nuclei, and of rapidly proliferating anaplastic cells.

(6) The occurrence of many amitotic nuclear divisions and of occasional abnormal mitotic divisions, i. e., divisions in which more chromosomes pass to one pole than to the other.

TUMOR CELLS FROM TUMOR CELLS.

A study of the growth of the crown gall shows that certain cells which have received the initial stimulus (infected needle pricks in our experiments) divide repeatedly and often very rapidly (Bul. 213), giving rise to a mass of soft tissue which is not inclosed in a capsule but grows peripherally, infected mother cells giving rise to daughter cells, and so on, indefinitely. These cells also stimulate other uninfected cells into rapid growth. Unlike the reparation of a wound, the growth is not limited to the physiological needs of the plant, but continues removed from the control of the plant except in so far as it is dependent on the latter for its food and water supply.

Apparently any meristematic cell may originate such tumors, but if they are not provided with a stroma they remain small and soon perish. This conclusion is based on a series of shallow versus deep inoculations into daisy stems. When the needle punctures were only 0.5 mm. deep, i. e., only into the region of the cork cambium, a stroma appeared, but the nodules remained small, and rotted away within a few weeks. When the needle pricks were 1 mm. or more in depth, i. e., when they entered the cambium region of the stem, much larger and longer-lived tumors resulted and these were abundantly vascularized.

GIANT CELLS.

Multinucleate cells occur which are perhaps comparable to the giant cells of the animal histologist. Cancer specialists have divided these into two groups, viz, foreign-body giant cells in which the stimulus is some introduced foreign substance, and genuine ones in which no foreign bodies are visible. There is probably no real distinction other than that those occupied by parasites are malignant and those induced by non-living granules are harmless. The cells in question in crown gall are not very large, but they contain several nuclei. Four nuclei in one cell is the most we have seen, but it is probable that larger numbers occur.

It would seem from our studies, which, however, are incomplete, that most of the cell divisions in crown gall are by mitosis. Frequently, however, we have found nuclei variously lobed and in process of amitotic division, and this is probably the way in which several nuclei are formed in one cell. (See fig. 1 and top figure of Pl. CVIII.) The whole subject of the cell mechanics of the tumor is reserved for further study.

THE STROMA.

Pari passu with the growth of the tumor cells new supporting tissues are developed in the tumor in various places. These supporting tissues consist of pitted vessels and wood fibers, but frequently the latter are scanty or absent. Sieve tubes are also present and are conspicuous in the outer part of secondary tumors. Spiral vessels are sometimes present in the tumor tissue, but never as *new growths.* They occur only as fragments ruptured from their normal position and carried away by the overwhelming growth of the tumor tissue.

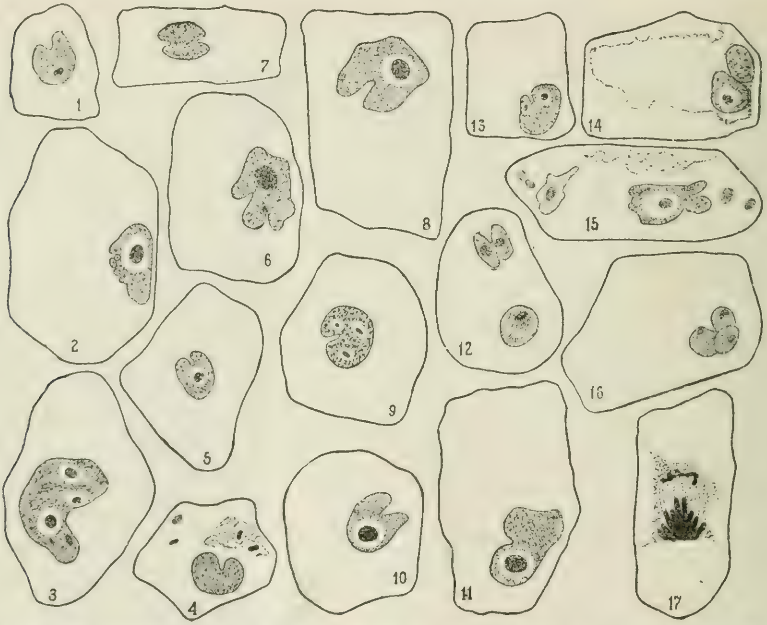

FIG. 1.—Nuclear divisions in crown gall: Nos. 1 to 16, cells showing stages of amitotic division; No. 17, mitotic division in which more chromosomes have passed to one pole than to the other. Material fixed in Flemming, and stained with Heidenhain's iron hæmatoxylin.

A most interesting question arises here: Does the stroma originate in the tumor, or is it a growth from the surrounding tissues? Studying the origin of the pitted vessels in secondary tumors it seemed at first as if they must be derived from the already existing leaf trace, stimulated into abnormal development by the presence of the tumor strand, but such is not usually the case. They are developed in most instances, so far as we have been able to determine, out of the tumor strand itself. Wood fibers when they are present, and likewise the sieve tubes, originate in the same way. This should not seem strange, since the tumor strand is an actively growing meristematic tissue. In some cases, however, the extreme edges of the cambium of the leaf trace seem to proliferate tracheids, which enter the tumor. Further studies will be made.

That the pitted vessels of the stroma are *new growths* admits of no doubt whatever. Their number in secondary leaf tumors far exceeds the normal number in the leaf trace, often as much as 100 to 1, and in early stages of development, such as that shown on Plate XLVIII, we have succeeded in tracing the abnormal vessels into the tumor strand, finding tracheids on one side of the abnormal meristem and sieve tubes on the other side, the tissues of the leaf trace being either uninvolved or only slightly affected. The pitted vessels found in the tumor serve to furnish it with water for its growth. This growth, when the stroma is abundant, forms a very hard, slow growing, fibrous, and resistant mass. But often the galls are soft and much exposed to decay, and in such cases the stroma is scanty and the woody part of it composed only of scattering pitted vessels unsupported by wood fibers. There are all sorts of transitions between these two conditions.

THE TUMOR STRAND.

Soon after the appearance of a primary tumor, particularly if the plant is well nourished and growing rapidly, tumor strands push out of it into the normal tissues, generally, it would seem, along lines of least resistance. These, of course, are invisible externally, but may be found by dissecting the basal parts of the tumor, and if of any size they are readily detected without the use of the microscope, i. e., by their peculiar structure and color (daisy). Subsequently when they are extending in thin leaves they may be recognized sometimes by a slight tumefaction on the midrib or leaf vein, which ceases beyond the advancing tip of the strand; and especially by the development on the strand of secondary tumors hidden at first by the overlying normal tissues of the leaf but soon giving to the latter a puffed-up appearance and subsequently coming to the surface of the plant by crushing and rupture of the overlying parts. Secondary tumors are a very common phenomenon in the Paris daisy and always, so far as observed, they are outgrowths from the deep-lying tumor strand, which is itself an outgrowth of the primary tumor.

This tumor strand in the Paris daisy makes its way exclusively, so far as observed, in the protoxylem region of the plant, i. e., in the region of the primitive spiral vessels, where it is often under great pressure, especially in the stem. (Pl. LXII.) So far as known, the tissues under pressure are not absorbed, but they are often flattened, crushed, split open, and exfoliated by the growing tumor. In a tobacco stem a tumor strand was observed in the bark parenchyma. In a number of instances we have found short tracheids in process of development directly from cells of the tumor strands, their lignification being yet incomplete and their nuclei still present. (Pl. LXVIII.)

STRUCTURE OF SECONDARY TUMORS.

If this disease were a granuloma we should expect the secondary growths to take on the structure of the organ in which they are located but such is not always the case.

When primary tumors develop in the top of beet roots, the secondary tumors in the midrib of the leaf have the many-ringed structure of the root. Usually when primary tumors develop on the soft stem of a Paris daisy secondary tumors appear in the leaves after a few weeks, and these tumors have a distinct *stem structure*—a structure which is not that of the leaf but of an invading destructive growth. This growth appears in one or more of the leaf traces, first as a tumor strand. This strand proliferates a variety of tissues—pitted vessels, sieve tubes, wood fibers (?), and medullary rays. These new vessels make the stroma of the tumor which, by fusing with the leaf trace, causes that part of the leaf to assume the form of an imperfect, rather fleshy, perishable *stem*, the tumor strand occupying the center.

This is such a peculiar phenomenon and so unlike anything hitherto known in plant diseases that the reader might well be excused for scepticism; the statement, however, is well supported by many observations and admits of no doubt, as may be seen from the accompanying photomicrographs.

ETIOLOGY OF THE TUMOR.

The cause of this disease is a schizomycete, *Bacterium tumefaciens* Smith and Townsend. The proofs of this statement, together with the morphological and cultural characters of the organism were given *in extenso* in Bulletin 213, Bureau of Plant Industry, and will not be rehearsed here.[1] Earlier papers also may be consulted. The organism was described and named after careful determination of its pathogenic properties April 26, 1907 (vide Science, n. s., vol. 25, p. 672, and Centralb. f. Bakt., 2 Abt., XX Bd., p. 89). Following the chart of the Society of American Bacteriologists, the group number of this organism is 212.2322023.

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[1] Copies of Bulletin 213, Bureau of Plant Industry, U. S. Dept. of Agriculture, issued Feb. 28, 1911, may be had from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price 40 cents. Add 10 cents for postage to foreign parts.

LOCATION OF THE BACTERIA.

The bacteria causing this neoplasm are located inside the cells, and it is the stimulus of their presence which causes the cell to divide abnormally by throwing it out of balance. Probably this stimulus also extends to many surrounding uninfected cells.

Since we have known the peculiarities of our organism it has been possible to prove, by means of agar poured plates, that the bacteria occur not only in the primary tumor but also in the secondary tumor and in the connecting tumor strand. By means of subcultures from single bacterial colonies we have produced the tumor hundreds of times (Bul. 213, p. 133), but it has not been easy to demonstrate the bacteria microscopically in the tissues. In most plant diseases of bacterial origin hitherto investigated (and the senior writer has been engaged in their study for more than 19 years) the demonstration of the bacteria in the tissues is a comparatively simple affair for any one possessed of fairly good technique. Not so here. We have believed for a long time that the locus of the bacteria must be the interior of the proliferating cells, because high powers of the microscope show that in rapidly proliferating tissues exactly like those known by the poured-plate method to contain the organism there are no granules (bacterial or other), either in the intercellular spaces or in the vessels, except sometimes near the entrance of the needle. Now if an organism is known to be present in one of three places and is not present in two of them, it must occur in the third. Both by diffusion from thin sections and by poured plates we have proved the bacteria to occur in the tumor, and if they do not occur between the cells or in the vessels, and the microscope shows that they do not, then *they must occur* within the cells. There is no other alternative unless we suppose them ultramicroscopic, i. e., totally unlike their form on culture-media, and also unlike the rods and Y-shaped bodies that diffuse out of the sections. (Fig. 2.) Then, of course, they might occur anywhere. Moreover, for such proliferation phenomena as that here described, extending as it does in a narrow cord of cells long distances from the primary tumor, it appears to be absolutely essential to the understanding of the mechanism of the controlling cell divisions that the stimulus should come from within the cell.[1] And that it does come from within admits of no doubt. First, as we have said, because there are no bacteria in the vessels or spaces between the cells; second, because we have occasionally seen rod-shaped, jointed, bacteria-like bodies moving about slowly within the living cells; third, because in a few instances we have been able to see them sharply delimited in stained preparations (Pls. CV, CVI, and CVII), and have not been able to find similar bodies in rapidly growing healthy tissues treated in the same way; and fourth, because the bacteria occur in the tumor strand and in the secondary tumor (evidence of colonies on poured plates and successful inoculations with subcultures therefrom).

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[1] It is inconceivable to the writer that a foreign organism, by any localized and brief presence in the tissues, should so modify cell inheritance that, after the organism and its products have disappeared, the cells should continue to develop abnormally rather than return to their normal habit.

The difficulty of demonstrating bacteria within the cell lies in the fact that commonly they are not very numerous and are mixed in with various cell inclusions which also stain with all the common bacterial stains, and some of which interfere with their satisfactory identification. No one who has not investigated the minute structure of the cell under high powers of the microscope knows the difficulties which lie in the way. The organism stains readily when taken from cultures, but practically all of our attempts to differentiate it in thin sections using the common basic anilin stains have been failures.

As in leprosy, these bacteria are in the protoplasm of the cell, *but not within the nucleus.* This seems to be made out with sufficient certainty by means of gold chloride impregnations which have given beautifully clear pictures, i. e., a farrago of granules (gold precipitates) and small groups of rod-shaped bodies resembling bacteria (some in division) stained deeply in the protoplasmic sac with the nucleus absolutely free and pale almost to invisibility. The protoplasm of the cell outside of the nucleus likewise remains colorless. By counterstaining with eosine the protoplasmic masses and the cell walls also become well defined. With the substage diaphragm wide open the granules are brown dots of various sizes, while the bacteria are deep blue-black rods, often crooked, or in clusters, pairs, chains, short filaments, or involution forms such as occur in culture media. When the diaphragm is closed the granules become paler (a gold color), but the bacteria retain their deep blue-black color. Sixty such rods were counted in the field from which figure 1 of Plate CV was photographed.

The group of bacteria shown in figure 1 is in the interior of a section 15μ thick. Figure at right is from same spot as 1, at a different focus. It shows 8 bacteria, 4 out of focus. As many as 100 bacteria have been seen within a single cell, all beautifully sharp (vide Plate CVI), but usually we found a lesser number and frequently none whatever, as though only a portion of the cells were occupied by them. Indeed, it would seem from our preliminary studies as though less than 1 per cent of the cells of the tumor are actually occupied by the bacteria. We hope to discuss this phase of the subject more fully in a subsequent bulletin.

By nitrate of silver impregnations we have also stained bodies within the cell which appear to be bacteria, and occasional cells show these in large numbers, but most of them only sparingly. In general, this method, which we tried first, seems less good than the gold chloride method.

The best preparation yet obtained for showing cell inclusions, which are not bacteria but might easily be mistaken for bacteria and were so mistaken by us at first, is a very thin section (5μ) stained by Gram but washed in amyl alcohol. This leaves the violet-blue stain in many kinds of bacteria from which the ethyl alcohol of the true Gram's stain removes it, *Bact. tumefaciens* in cultures being one of these. It was therefore thought to be well adapted for demonstrating them in the tissues. The material from which this section came was fixed in a moderately strong Flemming. The section was stained deeply and washed until very little color remained in the tissues. Most or all of the stained bodies at first suspected of being bacteria are probably lenticular chloroplasts seen on edge. These divide in the same way as bacteria, but they are not rounded at the ends. They can be distinguished from the latter also by the fact that they are not clustered and are circular and pale when not seen edge on. In the sections they show when seen on edge the same intensity and hue of color as the nucleus. These bodies are shown in Plates CVIII and CIX. Many times at least they appear to lie embedded in the wall of the protoplasmic sac (Pl. CIX). Sections stained with Heidenhain's iron haematoxylin also show these bodies very well.

One of the best evidences of the occurrence of the bacteria in the cells is the demonstration of Y-bodies, since there is nothing likely to assume this form in the normal cells of the plant. In Bulletin 213 (p. 107) we figured and described Y-shaped bodies which were obtained from cultures of *Bact. tumefaciens.* These occur in cultures exposed to low temperatures, to sodium chloride, to acetic acid, or to the by-products of the growth of the organism in the presence of peptone and sugar. They are fairly common in old cultures and are not unlike those assumed by many other bacteria when subjected to adverse conditions, e. g., bacteria occurring in the root nodules of legumes. At that time we believed them to occur also in the plant and to be responsible for the slow initial development of the poured-plate colonies (Bul. 213, p. 168), but had not found them. We have now found them *in situ* in the cells of the tumor (Pls. CV, CVI, and CVII) and have obtained them both from the sugar beet and from the daisy by allowing thin sections of fresh tumors to diffuse in water (double distilled from glass) on sterile slides (fig. 2). There is no doubt whatever as to their occurrence in the cells of the tumor, and we now have a sufficient and satisfactory explanation for the often observed slow development of the bacterial colonies on plates inoculated directly from the tumor (vide Bul. 213, pp. 22, 108, 168), because it is a well-known fact that involution forms are either dead or so reduced in vitality as to be slow to resuscitate. Those we obtained by adding dilute acetic acid to young agar and bouillon cultures were either dead when tested on agar poured plates or developed colonies slowly.

TWO HYPOTHESES.

I. *Hard versus soft galls.*—Whether a crown gall shall develop as a hard gall or a soft gall would seem to depend chiefly if not altogether on which meristem cells receive the initial impulse. If the cells first infected are principally the mother cells of medullary rays, we may assume that the gall will be a "soft gall," and readily inclined to decay. If, on the contrary, the needle or other carrier of infection wounds principally those meristem cells which give rise to tracheids and wood fibers, the gall will be a "hard gall," of slow growth and long

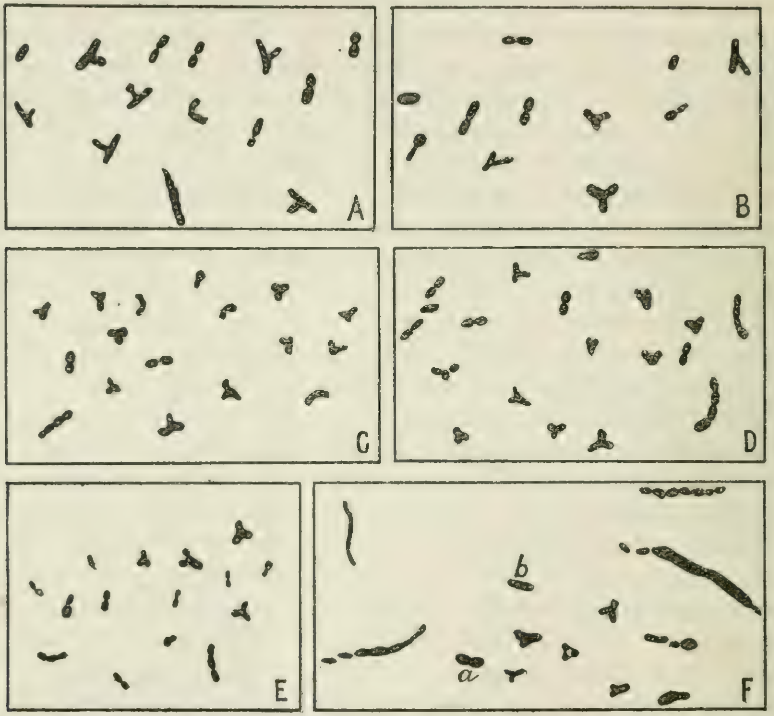


FIGURE 2.—Free-hand drawings of rods and involution forms of Bacterium tumefaciens made in 1911 from young tumors, the slides being obtained by allowing sections of the galls to diffuse for an hour in distilled sterile water, after which they were removed, the fluid on the slides evaporated, and the residue stained 20 to 30 minutes in a dilute solution of basic fuchsin. The surface of the gall was removed with red-hot knives before making the sections, and all of the instruments and fluids were free from bacteria: *A*. Daisy on daisy, May 25 (Brown). About 1 sq. cm. examined in 2 hours; *B*. Daisy on daisy, May 23 (Brown), 2 sq. cm. of slide examined during 5 hours, several other Y's seen; *C*. Hop on red table beet, May 20 (Brown); *D*. Hop on red table beet, May 19 (Brown); *E*. Hop on sugar beet, May 18 (Smith). The rods were about 1.5 to 2 μ x 0.5 to 0.7 μ. There was not more than one distinct one per field (2 mm. Zeiss 1.30 n. a. oil im. obj. and No. 8 comp. oc.). Frequently one of the two segments of a pair was swollen. More than twice as many involution forms were seen as drawn. There was about one to every 8 or 10 fields. About 10 sq. cm. of the slide were examined. *F*. Hop on sugar beet, slide XXX, May 19 (Smith). Another part of *E*. Eight Y's not drawn. All well stained with diaphragm wide open; *a* measured 1.3 x 0.8 μ; *b*, 3 x 0.5μ, the latter was by itself, i. e., free from other granules with perfectly sharp margins and a deep stain.

duration. This hypothesis would seem to account for all the histological differences observed in crown galls and for at least a part of their recognized gradations in virulence.

II. *Crown gall a symbiosis.*—The relation between host and parasite in this disease may be regarded as a symbiosis in which the bacterium has the advantage. It derives its food from the cells of the host, and drives them at a breakneck speed. It gives to them in return its waste carbon dioxide for the use of their chloroplasts. It does not destroy the cells of the host, but only stimulates them into an abnormal and often exceedingly rapid division. This stimulus, it would seem, takes place through the following delicate adjustment of opposing forces: Within the host cell the sensitive parasite produces as one of its by-products an acid. As this accumulates it stops the growth of the bacteria and destroys a portion of them, without, however, destroying the host cell. The membranes of these dead bacteria, which have now become permeable, allow the diffusion into the host cell of bacterial endotoxines. The host cell now contains, of abnormal bacterial products, (*a*) these escaped endotoxines, (*b*) a certain amount of weak acid (acetic?), (*c*) some ammonia, and (*d*) an excess of carbon dioxide. Under the stimulus of one or more of these poisons the nucleus divides by mitosis. In process of division the nuclear membrane disappears and the contents of the nucleus flows out into the cell. The dormant bacteria under the stimulus of this nuclear substance renew their activities in the daughter cells until again inhibited, whereupon the daughter cells divide. By this rocking balance, in which first the parasite and then the host cell has the advantage, the tumor develops rapidly and independently of the needs of the plant.

The facts underlying this hypothesis are as follows:

(1) *Evidence from pure cultures.*

(*a*) The development of Y-shaped and other involution forms in pure cultures of *Bact. tumefaciens*, subjected to unfavorable conditions.

(*b*) The development of an acid in sugared peptone water cultures, to the action of which acid the involution forms are attributed.

(*c*) Our ability to produce these Y-shaped bodies at will and promptly in young agar and bouillon cultures by addition of small quantities of dilute acetic acid.

(*d*) Proof from agar-poured plates that most or all of the Y-bodies developed in the presence of the acetic acid are dead, i. e., will not grow into colonies when copious sowings are made on agar plates.

(*e*) The observation that those bacteria which are not killed by exposure to the acid are so paralyzed that they come up more slowly on agar-poured plates than do those from untreated cultures.

(*f*) Production of ammonia by this organism in culture-media as one of the results of its assimilation of nitrogen compounds.

(*g*) While *Bact. tumefaciens* does not give off CO_2 in measurable quantities in fermentation tubes in the presence of sugar, it is assumed that such large volumes of the gas are not only not requisite but would be injurious to the mechanism of tumor development, and that all ordinary bacteria, including this one, throw off some CO_2 as a result of their growth.

(2) *Corresponding evidence from the plant.*

(*a*) To obtain *Bact. tumefaciens* from the tumors by means of agar-poured plates unusually heavy sowings must be made.

(*b*) These colonies often come up slowly as if the bacteria from which they have developed were nearly dead and must first recover from some inhibition before they can grow. Once recovered they grow satisfactorily.

(*c*) The existence of good-sized Y-bodies and variously deformed bacteria in the tumor tissue as shown by their diffusion from sliced tissues lying on flamed slides in bacteria-free water.

(*d*) Proof from ordinary sections, stained and unstained, that the bacteria do not occur in the vessels or the intercellular spaces of the tumor. There are no bodies of any sort in these places.

(*e*) Demonstration by impregnation with gold chlorid that the bacteria are not abundant in the tissues, that they occur *inside the cells but outside the nucleus*, and that Y-bodies and variously branched forms are common.

(*f*) The existence of an excess of CO_2 in the tumor cells is inferred from the behavior of the chloroplasts which multiply in the tumor strand and other deep parts of the tumor in large numbers so as to make the tissues decidedly green.

(*g*) A statement by the chemist that the same acid occurs in tumor tissue as in our flask cultures.

Up to this time we have not been able to determine the litmus reaction of the nucleus; neither have we been able to show conclusively that the acid produced in the tumor tissue is identical with that developed from grape sugar in our flask cultures. The uranium salts look much alike, but I am not sure that they are identical. Further studies will be made.

EFFECT OF CHROMATES.

Ever since we have known this neoplasm to be due to bacteria lodged within the cell, it has been a foregone conclusion that, however much the tumor cells might resemble meristematic or embryonal tissues morphologically, their chemical contents certainly must be somewhat different both on account of the by-products thrown off during the growth of the bacteria and by reason of reactions set up by the cells against the intruding organisms. In Bulletin 213, page 173, it was shown that the tumor tissue (sugar beet in that case) contains an excess of colorless substances oxidizing to dark compounds on exposure to the air. A further evidence of chemical difference is shown on Plate CIV. In figure 1 of this plate the deeply stained pieces represent portions of a daisy tumor soaked in water saturated with potassium bichromate. The unstained pieces are normal parts of the daisy treated in the same way. The brown stain appears slowly in cold solution but within a few minutes in hot ones. Potassium chromate and neutral ammonium chromate have the same action on the galled tissues, staining them a deep brown, whereas the normal meristematic tissues are only feebly stained. Chromic acid and chrome alum did not have this effect. The substance which causes this dark stain may be extracted from the tissues readily by hot alcohol, as shown in figure 2 of Plate CIV. Here the right-hand sections were exposed for a few minutes to the action of a hot saturated solution of potassium chromate. The sections at the left were from the same tumor and were treated in precisely the same way, except that they were first thrown into hot ethyl alcohol and allowed to simmer for a few minutes. That some substance is actually removed from the tissues is shown by the subsequent behavior of the alcohol in presence of these compounds of chromium. This reaction was discovered in making experiments to determine whether the appearance of the gold chloride preparations might not be improved by some preliminary treatment. It was hoped that a way might be found to remove some of the substances causing granular precipitates within the cell and so leave a clearer picture. Naturally we first thought of tannins. What this soluble substance is remains to be determined. Possibly it is a tannin, in which case the brown reaction might perhaps be considered as a phlobaphene reaction due to the acid radicle of the salts used.

NOTES ON TECHNIQUE.

The daisy plants described in the following pages are plants selected from a series inoculated especially for the purpose of studying the movement of the tumor strand and the development of stem structure in the leaves. All were inoculated at about the same time, a foot or more above the earth, and all in the young, rapidly growing stems, except those plants used for checks, i. e., those inoculated on the leaves. All of the inoculations were made by needle pricks without hypodermic injection. At the time of the inoculation the stems were soft and rapidly elongating, and the needle pricks were made in what was then the top of the plant. For inoculating material we used agar subcultures from single poured-plate colonies. All of the inoculated plants contracted the disease where pricked and not elsewhere, except as the result of invasions from the primary tumor.

We obtained a great wealth of pathological material of which only a part could be used for the preparation of this bulletin. The material selected for the sections was fixed in Carnoy's fluid (acetic acid 1, alcohol 3). Suitable pieces were then infiltrated with paraffin, cut on the microtome, usually in series, fastened to clean slides with egg albumen, and stained in various ways, none of which, however, demonstrated any bacteria in the tissues, i. e., not with certainty. We sometimes saw rods in these sections but could not be *sure*.

Many stains were tried. The best stain for differentiating lignified from nonlignified tissues proved to be that recommended by Chamberlain (Methods of Plant Histology, pp. 49 and 68), i. e., a prolonged stain in methyl green followed by a short exposure to acid fuchsin.

The photomicrographs were made on Hammer's double-coated nonhalation orthochromatic plates using monochromatic light (Zettnow's fluid). They were made with Zeiss apochromatic objectives and a No. 4 compensating ocular. All of the photomicrographs except a few at the end were made either with the Zeiss 16-millimeter or 8-millimeter objective. The source of the light was an electric arc. The developer used was rodinol, usually 1 part to 30 parts of water. The exposures were made by the senior writer, but the plates were developed and printed from by Mr. Brewer.

NORMAL ANATOMY OF THE DAISY.

So much will be said about abnormal phenomena in the stems and leaf traces of the daisy that some words of introduction are necessary respecting the microscopic structure of the normal plant, especially for those not familiar with the anatomy of plants.

STEM.

In the center of the stem is a *pith*. This is composed of nearly isodiametric cells which, as growth continues, become compressed in various directions by pressure of neighboring cells so that on cross section they are often hexagonal. This tissue, while remaining alive for a considerable period, remains dormant and functions chiefly as a storage system. At the periphery of the immature stem is a cylinder of coarse-celled, rather loose tissue known as *bark parenchyma*. The young stem is covered and protected from the air by a one-celled layer known as the *epidermis*, between which and the bark parenchyma one or more layers of cells with thickened angles may be present. This is known as *collenchyma* and functions as a strengthening tissue. Finally in this region a tissue develops which is known as the *cork cambium*. As the stem grows this cork cambium proliferates (slowly on the daisy), giving rise to layers of impervious cells (*cork*) which take the place of the thin, temporary epidermis. Between the bark parenchyma and the pith is a complex structure consisting of a series of elongated *bundles* radiating from the pith in every direction. These are few in number at first and separated by wide areas of looser tissue (Pl. I), but very numerous as the stem grows, and then separated by narrow, compressed plates of nearly isodiametric cells known as *medullary rays*. In the young stem these rays extend from the pith to the bark parenchyma. In older stems new ones arise from time to time and take their origin at more and more remote distances from the pith. Bordering these bundles externally, i. e., on the inner border of the bark parenchyma, is a layer of cells known from its contents as the *starch sheath*. The bundle consists principally of wood and soft bast or *xylem* and *phloem*, in the terminology of the anatomist. The structure in detail of a single bundle in such a stem is as follows: The xylem portion consists, at its older (innermost part), of a few *spiral vessels*, which do not increase in number; beyond these are *pitted vessels* (tracheids) and *wood fibers* (wood parenchyma) which are continually increasing in number as the stem grows. The phloem consists of *sieve tubes* (slime vessels) and *companion cells*. The longer axis of these vessels corresponds to that of the stem. As the stem increases in size *bast fibers* (groups of thick-walled elongated cells) appear in the outer part of the bundle not far from the phloem, i. e., inside the starch sheath. The phloem is separated from the xylem by the *cambium* which also separates the xylem part of the medullary ray from its phloem part. The cambium is the most actively growing part of the stem, giving rise to new bundles and increasing the size of the old ones, xylem tissues being laid down on the inner side of it and phloem tissues on the outer.

Plate I shows a cross section of a healthy portion of Daisy No. 1, branch II, from epidermis to pith. Beginning at the top, the tissues occur in order as follows: *E*, epidermis; *cc*, subepidermal layer; *cp*, cortical parenchyma with chloroplasts; *st*, starch sheath; *bf*, group of bast fibers; *p*, phloem; *c*, cambium; *t*, *sp*, xylem wedges (tracheids and spirals), which are heavily stained; *mr*, medullary ray; and *pt*, pith. As the stem increases in diameter the wood wedges become numerous and compacted into a thick cylinder, and then the epidermis is slowly replaced by bark. Section stained with methyl green and acid fuchsin.

Plate II shows in cross section a part of branch III, Daisy No. 1. Here the ring of wood is somewhat thicker, and the bast fibers are also more abundant. For appearance in cross section of the older stems containing a much greater quantity of wood, see Plates XXI, XXV, LXIII, LXVII, and LXXVIII.

When leaves or branches are given off from such a stem they include parts from all the various elements of the bundle as mentioned below.

LEAF TRACES.

Those vascular portions of the stem which pass out into leaves are known as *leaf traces.* In the daisy petiole there is a central leaf trace and several side ones. Farther out (on the lamina of the leaf) these leaf traces branch repeatedly, forming a supporting and conducting network, the so-called *veins* of the leaf. The appearance of a normal leaf trace in cross section is shown on Plate III. Beginning at the top of the plate (under surface of the petiole), the tissues occur in order as follows: *par,* loose parenchyma or ground tissue of the petiole; *st,* starch sheath, entirely surrounding the bundle; *scl,* thin-walled elongated supporting cells; *p,* pholem; *c,* cambium; *t,* tracheids of the xylem; *m,* medullary ray; *sp,* spirals of the xylem; *scl,* thin-walled elongated supporting cells; and *par,* surrounding loose-celled parenchyma of the petiole. On Plate IV may be seen the appearance of a similar leaf trace in longitudinal section, the top of this plate corresponding to the top of the preceding. Below the large spiral vessels are smaller spiral vessels and delicate ring vessels. It is through this region that the tumor strand passes. Plate V shows the appearance of a longitudinal section through a petiole between two leaf traces, i. e., through the ground tissue of the leaf from epidermis to epidermis. Portions of this tissue are often surrounded by and incorporated into the growing tumor.

The function of the xylem part of the bundle, aside from support, appears to be storage and movement of water; that of the phloem, storage and movement of elaborated nitrogenous substances. The pith and medullary rays are often used as starch receptacles. The bark parenchyma contains numerous chloroplasts whose function it is to convert water and carbon dioxide into sugar and starch. The pith, young wood fibers, and medullary rays also contain chloroplasts but in lesser numbers.

In considering the abnormal phenomena now to be described these plates illustrating the normal anatomy will be of prime importance.

BEHAVIOR AND HISTOLOGY OF SELECTED PLANTS SPECIALLY INOCULATED FOR THESE TESTS.

DAISY NO. I.

WHOLE PLANT.

(Plate VI.)

This plant was inoculated January 13, 1911, and photographed March 10, 1911. Primary tumors developed at *x,* where punctured. Secondary tumors afterwards appeared on leaves *A, B, C,* and *D,* as shown. After photographing, agar poured plates were made from the interior of each one of the branches (I, II, III) to determine whether the inoculated organism could be isolated therefrom. Plates were also poured from the secondary tumors on *A*, *B*, and *C*. Finally, portions (marked *F*) of the three branches and of leaf *C* were fixed, embedded, sectioned, and stained for demonstration of the tumor strand, if such existed.

The poured plates were as follows:

A (not burst through), 8 plates (Brown).
B (burst through), 5 plates (Hedges).
C (burst through), 7 plates (Brown).
I, 8 plates (Brown).
II, 6 plates (Hedges).
III, 7 plates (Brown).

Total, 41 plates. All negative or doubtful. One of the colonies which came up on the twelfth day from stem I looked hopeful and was transferred, but there is no record of inoculations.

The histology of the parts is shown in the following plates.

BRANCH III.

(Plate VII.)

Cross section of branch III, slide 575 C 1, in the lower part. This section shows the junction of wood and pith with a small tumor strand in the center of the picture. This strand passes from the primary tumor into petiole *C*. Section torn in mounting. For a normal part of the same section, see Plate II. For longitudinal sections of this strand farther away from the primary tumor, i. e., in the petiole, see Plates XVII to XX.

PETIOLE C.

(Plates VIII and IX.)

Cross section of petiole *C* (Pl. VIII), at one end of the lower fixed portion (slide 643 A 18), showing the enlarged and modified central leaf trace. The traces on either side of this one are normal. The parenchyma between the leaf traces is also normal, but is somewhat shrunken by the fixing agent.

In Plate IX the upper part of the middle leaf trace, slide 643 A 19, is enlarged to show the tumor strand. For a similar section from the other end of the fixed part of this petiole, see Plates X and XI, which should be compared with Plate III.

PETIOLE C.

(Plates X and XI.)

Plate X.—Cross section of central leaf trace at other end of the fixed portion of petiole *C*, slide 643 B 6, showing abnormal wood wedges. The original leaf trace is at the lower and left part, somewhat enlarged and distorted, but otherwise nearly unchanged. The upper portion of this leaf trace enlarged to show the tumor strand may be seen in Plate XI, made from another slide in the same series (643 B 12).

BRANCH I.

(Plates XII, XIII, and XIV.)

The varying appearance of the tumor strand at various levels in the same series of sections is well illustrated in Plates XII to XIV, made from branch I under petiole *A*. (See Pl. VI.) Here the tumor strand (block 575 A, slides 8, 10, and 11) is in the inner wood next to the pith. In Plate XII it consists exclusively of small cells. In Plates XIII and XIV there are also in it large soft cells with very conspicuous nuclei. In Plate XIV, in the lower part of the strand, are tracheids developed from cells of the tumor strand and twisted at right angles to their normal direction. This is a common occurrence.

BRANCH II.

(Plate XV.)

Cross section of branch II, slide 575 B 10, just under petiole *D*, showing a somewhat irregular tumor strand in the xylem part of the bundle. In the lower part of it, near the pith, are twisted tracheids developed from the tumor strand. Above is infiltration.

PETIOLE C.

(Plate XVI.)

Tumor tissue from petiole *C*, slide 643 C 39, showing many cells with 2 nuclei. It is all rapidly proliferating parenchyma, but the cells are growing in different directions.

PETIOLE C.

(Plates XVII, XVIII, and XIX.)

Plates XVII to XIX are sections of the upper portion of the fixed part of petiole *C*, i. e., they are the same as Plates IX and XI, but cut longitudinally to show the extension of the tumor strand. The plates were made from block 643 *c*, slides Nos. 23, 21, 19, and 17. The top of the plate represents the proximal part of the petiole. The strand, which comes from the stem, has developed the small unruptured tumor *M* (Pl. VI), and thence passed into the part here shown. The small, rapidly proliferating neoplasm shown at the bottom of Plate XVIII is not yet large enough to be indicated by any surface swelling. In XVII and XVIII, *x* corresponds to *x*. The distal part of the strand in greater detail is shown on Plate XX.

PETIOLE C.

(Plate XX.)

Plate XX shows a longitudinal section of petiole *C,* one field beyond Plate XIX, i. e., its top joins on to the bottom of Plate XIX. In the center of the plate is the tumor strand, to the left are spiral vessels, to the right is a portion of the tissue marked "scl" in Plate III, with which, and Plate IV, this should be compared.

DAISY NO. II.

CROSS SECTION OF STEM.

(Plate XXI.)

One of the plants inoculated January 13, 1911, and fixed March 23, 1911. This plate gives a cross-section of the stem, slide 641 A 13, between the primary tumor and a secondary one and shows a well-developed tumor strand on the lower right-hand side at the junction of wood and pith. The wood is enlarged a little near the strand, but otherwise it is normal. The bark is also normal. The pith cells are flattened next the tumor strand by pressure, but farther away are normal. For a detail see next plate.

TUMOR STRAND IN STEM.

(Plate XXII.)

Plate XXII, from slide 641 A 13, gives an enlargement of the tumor strand shown on Plate XXI. The black dots are nuclei. The figure shows a vague demarcation at the top where the tumor strand shades into the modified wood, and a sharp one below where the pith cells are flattened by pressure. At *sp.* are several rows of crushed spiral vessels; at *X*, *Y*, *Z*, are displaced spiral vessels. This section was stained with methyl green and acid fuchsin.

DAISY NO. V.

WHOLE PLANT.

(Plate XXIII.)

This plant was inoculated January 13, 1911, and photographed March 27, 1911, three-fourths natural size. Primary tumor at *X* where the needle pricks were made. Secondary tumors on leaves *A*, *B*, and *C*. Both *A* and *C* have split open. Several small roots were projecting from the base of the primary tumor on this side, but are hidden by the apex of leaf *B*. For the back view of this plant, see Plate XXIV.

WHOLE PLANT, BACK VIEW.

(Plate XXIV.)

Plate XXIV gives the opposite side of the plant to that shown on the preceding plate. *A* and *C* correspond. *B*, which has been shortened to a stub, is invisible. At *D* are secondary tumors in the base of a leaf, the remainder of which has shriveled under the influence of the disease. Four leaves on this side between *C* and *A* were free from visible growths. They were removed before photographing for clearness sake. Roots stimulated into development by the presence of the tumor are present at *RR*. The stem between *E* and *F* was removed; photographed end on, at *F* (see lower left part of the plate); and then split longitudinally, along the median line (see lower right part of plate). In the middle of the vertical section is an expansion of the green tumor strand which later on might have burst through the wood and bark and appeared as a surface tumor. Secondary stem tumors of this sort are now present in the hot houses. The cross section shows enlargement of the wood on one side and a distinct green tumor strand between wood and pith. For the minute anatomy of the stem at this level, see Plate XXV.

CROSS SECTION OF STEM.

(Plate XXV.)

Cross-section of stem, slide 594–8, at the level of *F* in Plate XXIV, showing the large tumor strand with thickened wood cylinder on that side only and absence of thickening in the bark. Under a hand lens the duplication of medullary ray cells near the strand may be seen in the photograph but is lost in the half tone. The pith is normal except in the vicinity of the tumor strand where it is flattened.

Section stained with Ehrlich's acid hematoxylin. The strand is redder than the other tissues.

For details from the tumor strand see Plates XXVI and XXVII.

A DETAIL FROM THE TUMOR STRAND.

(Plate XXVI.)

Plate XXVI, from slide 594–8, gives more highly magnified the upper portion of the tumor strand shown in Plate XXV. At the left are the cells of the tumor strand; at the bottom, top, and right side is the modified wood. The demarcation between the modified xylem and the tumor strand is somewhat vague. The black dots are deep-staining nuclei.

DETAIL FROM THE TUMOR STRAND.

(Plate XXVII.)

Plate XXVII, from slide 594–8, gives the lower part of the tumor strand shown on Plate XXV. The cells of the tumor strand are at the right. The pith is at the left and its cells have been flattened by the pressure. The demarcation between the tumor strand and the pith is sharp.

DAISY NO. VII.

Whole Plant.

(Plate XXVIII.)

This plant was inoculated on January 13, 1911, and photographed March 31, 1911, about two-thirds natural size. The bacterial culture was introduced at *X X*, where the primary tumor soon developed. Secondary tumors developed on leaves *A*, *B*, *C*, *D*, and *E*, and also in the interior of branches I and II. Material at *F* was fixed for microtome sections from stem I and from leaves *A* and *D*. Petri-dish plates were poured from the interior of *A*, *B*, *C*, and D. Pieces from the interior of I and II were also transferred to tubes of bouillon and incubated.

The plant was 8 months old and 24 inches high. It divided into two equal branches, both of which were inoculated. One branch only is shown in the photograph (for notes on the other one see below). The inoculation was made 11 inches from the ground. The actual distances at the time the photograph was made were as follows: Origin of leaf *A* to primary tumor, 6 cm.; length of infected portion of leaf *A*, 9 cm.; origin of *A* to base of *B*, 5.5 cm.; base of *B* to its tumor, 4 cm.; total distance from primary tumor to tumor on *B*, 15.5 cm.; time, 77 days; top of *C* to origin of branch bearing it, 5 cm.; origin of *D* to junction of II with main stem, 4 cm.; length of secondary tumor on *D*, 6 cm. At *Y Y* the petioles in cross section are circular and resemble stems, i. e., they have a narrow green pseudopith, a wide ring of wood, and beyond this a cambium and phloem. All that distinguishes *D* as a petiole are the unchanged petiole wings. For the appearance of microtome sections from these petioles see the following plates.

Both above and below the swelling on I there is a thickening of the wood on one side, and in the inner part of this next to the pith is a green strand of tumor tissue about 1 mm. in diameter.

The following are notes on the inoculated branch which was not photographed:

The primary tumor is now 2 by 1.5 inches in diameter. The main axis has been dwarfed by the growth of the primary tumor to a tiny shoot 3 inches high. This is 2 to 3 mm. in diameter, except at the base, which is much swollen by an internal tumor not yet ruptured to the surface (this part is 1 cm. in diameter). Four centimeters above the base a leaf arises which bears secondary tumors in the midrib for a distance of 5 cm. Under the primary tumor, coming out of the wood and bark is a cluster of nine small roots. On the back side, in the same relative position, are eight other small roots.

The primary tumor has also grown into the base of three other shoots as follows: (1) Right-hand shoot, arising from the middle of primary tumor, where all but the base of the shoot has been destroyed, the latter being occupied by a living tumor 3 cm. long and 2 cm. broad. (2) Left-hand shoot, arising near base of primary tumor, bears a ruptured tumor for a distance of 4 cm. and thence appears sound externally for a distance of 10 cm., where it gives off a leaf that at a distance of 7 and 8 cm., respectively, from its junction with the stem, shows on the midrib two unruptured secondary tumors, the remotest one being, therefore, 22 cm. from the primary tumor and 17 cm. from any surface indications of disease. (3) In the middle back part of the primary tumor a stem arises which shows no surface tumors, but is swollen and bears two leaves with secondary tumors, diameter of stem at base being 5 mm., but 2 cm. up (in swollen place) it is 8 mm. in diameter. The first diseased leaf arises at a distance of 5 cm. up and shows ruptured tumors for a distance of 6 cm. on the midrib. Two centimeters farther up the second leaf arises and this bears secondary tumors on the midrib for a distance of 2 cm.

The tumor stimulus has extended down the main stem, but much less conspicuously. It is visible for a distance of 8 cm. below the main tumor, as shown (1) by a root pushing out 3.5 cm. below, and (2) by a small secondary tumor in a leaf scar 8 cm. down. Here the stem is 1.5 cm. in diameter and quite woody. In a hasty examination I could find no tumor strand in the interior of this hard stem.

The cultures were negative or doubtful, as follows: Petiole *A*, no gall colonies; petiole *B*, no gall colonies; petiole *C*, one gall colony, daisy inoculation therefrom negative; petiole *D*, no gall colonies; stem I, no gall colonies on plates poured from three tubes after clouding; stem II, after six days very suggestive stringy filaments in both tubes. Plates from one gave only pink colonies, plates from the other gave colonies which for a time very much resembled the daisy organism, but we finally rejected them as intruders. Two of the four tubes of II inoculated with large pieces of the stem never clouded (17 days), and also one of the four of stem I.

PETIOLE A.

(Plate XXIX.)

Plate XXIX, from slide 592 B 17, gives the base of petiole *A* in cross section, showing conversion of the central leaf trace and two side traces into secondary tumors having stem structure. A tumor strand occupies the center of each modified leaf trace. The only unchanged parts of the petiole are the periphery and the marginal wings. The primary xylem of the leaf trace occupies about one-fourth of the present wood cylinder, i. e., that on the right side.

For a detail from the center of the middle tumor see next plate. Section stained with methyl green and acid fuchsin.

PETIOLE A.

(Plate XXX.)

Plate XXX, from slide 592 B 17, gives the center of the middle leaf trace from Plate XXIX enlarged to show the character of what may be called the pseudopith, i. e., the rapidly proliferating tumor strand, in the center of the pseudostem. Woody tissues at top and bottom. In the lower right corner an abnormal medullary ray.

PETIOLE D.

(Plate XXXI.)

Cross section of petiole *D*, slide 592 A 15, showing conversion of the petiole into a secondary tumor which has not yet ruptured to the surface. Stem structure plainly visible. Several infected leaf traces have fused. The central tumor strand is conspicuous. The margins of the petiole are not involved; but for these no one would suspect this to be a petiole. The actual diameter of the mounted section is 8 mm. The primary xylem of the leaf trace appears to be on the lower right hand side. Section stained with Ehrlich's acid hematoxylin.

DAISY XI.

WHOLE PLANT.

(Plate XXXII.)

This plant was inoculated January 13, 1911, and photographed April 5, 1911, about three-fourths natural size.

The primary tumor, *X*, *X*, induced by needle pricks, surrounds the stem except as here shown. Secondary tumors developed after some weeks on *A*, *B*, *C*, and *D*. Leaf *D* has shriveled to a stub. The growth in *A* has ruptured to the surface but not in *B* except near the apex. The terminal part of *B* was removed earlier for study. On dissection a green strand of soft tumor tissue was traced from the primary tumor into both *A* and *B*. The petiole *B* in the vicinity of *M* was found to have stem structure in the middle leaf trace and was fixed for sections (Pl. XXXIV). In the main stem at *P*, i. e., just under the attachment of leaf *C*, a green strand of tumor tissue was visible under the hand lens, but was inconspicuous. For the appearance of this strand when more highly magnified see Plate XXXIII.

CROSS SECTION OF STEM.

(Plate XXXIII.)

Plate XXXIII, from slide 591 AA 3, gives a cross section of the stem at the lower line of *P*, i. e., just under origin of the infected leaf *C*. It shows an abnormal soft tissue strand in the wood somewhat farther away from the pith than customary. The vessels of the single row below this strand are spirals. Pith cells at the bottom. Stained with methyl green and acid fuchsin.

PETIOLE B.

(Plate XXXIV.)

Plate XXXIV, from slide 591 B 8, gives a cross section of base of petiole *B* showing stem structure in the central leaf trace. In the center of this tumor is the tumor strand; to the right is the original xylem of the leaf trace more broken up and disorganized than in Plate LII, i. e., there appears to have been an invasion of soft cells from the tumor strand or a stimulus to increased development of the medullary rays from proximity to that strand. In other directions may be seen the abnormal wood wedges separated by wide areas of nonlignified tissues—medullary rays, etc. Beyond is cambium and beyond that phloem. At the extreme right beyond (outside) the phloem are a few thin-walled pitted vessels in what appears to be a small modified misplaced leaf trace, or portion of such a trace.

The small black specks in the central strand are normal and crushed spiral vessels wedged off from the base of the primary xylem of the leaf trace by the growth of the tumor tissue. These appear to be a portion of the original spirals of the leaf trace. All the *new* vessels forming the abnormal wood wedges are tracheids, i. e., short pitted vessels. These are stained blue in the section and are dark in the photograph.

PETIOLE B.

(Plate XXXV.)

Plate XXXV, from slide 591 B 6, gives the middle portion of the modified middle leaf trace of petiole *B* at about the same level as Plate XXXIV, enlarged to show the character of the tumor strand which contains both pitted vessels and spiral vessels. The primary wood wedges of the leaf trace are in the upper right hand corner. Projecting into the tumor-strand from this part crushed spiral vessels may be seen. Section stained by Gram-eosin.

PETIOLE B.

(Plate XXXVI.)

Plate XXXVI, from slide 591 B 2, gives a cross section of the middle portion of the infected leaf trace of petiole *B* in vicinity of *M*, showing two of the three whorls of small cells surrounded by tracheids.

These are on that margin of the tumor strand remotest from the primary xylem of the leaf trace. They are not visible on Plate XXXV. Section stained with methyl green and acid fuchsin.

In the middle of the figure on the right side are tracheids twisted at right angles to their normal direction.

DAISY XII.

WHOLE PLANT.

(Plate XXXVII.)

Plant inoculated by needle pricks on January 13, 1911, and photographed April 5, 1911, nearly natural size. Primary tumor, *X*, *X*, mostly on the reverse side of the plant where pricked. Secondary tumors on petiole *A*, which has ruptured, and on *B*, which has not yet broken open. Behind *A* was a third leaf occupied by secondary tumors and now shriveled to a stub. In cross section at *M* the petiole *A* shows stem structure, i. e., a green pseudopith, greenish wood cylinder (complete), cambium ring, and phloem. In the lower part of the picture (magnified about 2 diameters) is a cross section of petiole *A* where at *X* and *Y* are shriveled remnants of the wings of the petiole. This may be compared with the earlier stage shown in Plate XXXIV and the still earlier stage on Plate XLVII. Here the petiolar tissue outside of the tumor is entirely destroyed. Although *A* is circular in cross section at *M* and has a diameter of 9 mm., it is attached to the stem by a small, shriveled pedicel, i. e., the remnant of the petiole base. The stem was split along the vertical line and then cut crosswise at O to O^3.

At the level of O, deep in the stem, was a soft, green strand of tumor tissue nearly circular and about 1 mm. in diameter, proceeding from the primary tumor toward *A*. Under the microscope this appeared to be totally unlike either wood or pith. It was on the tumor side of the stem in the wood, but near the junction of wood and pith. This tumor strand was also visible to the naked eye or with the hand lens at O^2 and O^3, but not at O^1. However, when fixed, embedded, sectioned, stained, and examined under the compound microscope, it was visible here also (see Pl. XXXVIII). For appearance of petiole *B* in cross section at various levels, see Plate XLII and the following ones.

CROSS SECTION OF STEM.

(Plate XXXVIII.)

Plate XXXVIII, from slide 590 $C^1 1$, gives a cross section of the stem at O^1 (see Pl. XXXVII), showing a tumor strand at the inner border of the wood next the pith. Some of the pith cells at the bottom of the picture are shriveled, owing to the fact that the stem segment was cut diagonally and these cells border on the extreme edge of the cut. Above this strand, in a vertical line, is a row of spiral vessels (walls stained blue). On a right line with these in the lower part of the strand is a lignified vessel of another type (tracheid), the blue wall being represented by a wide black border (it is the immature cell containing an elliptical nucleus). The walls of the other bordering cells and of the strand cells in the section are stained red. Other sections in this series also show tumor-strand cells in process of conversion into pitted vessels.

Section stained with methyl green (for the xylem) and acid fuchsin (for the protoplasm and cellulose walls).

PETIOLE A.

(Plates XXXIX and XL.)

Frequently inside a tumor several proliferation centers of soft, small cells may be seen surrounded by whorls of tracheids, as shown in Plates XXXIX and XL, made from different areas in the same slide (590 A 7). Cut at right angles to sections here shown, they appear as strands, and which often pass out toward the surface of the growth. There are two of these whorls in petiole *A* at the level of this section. They are near the center on that side of the tumor strand (Pl. XLI) remotest from the original xylem wedges of the leaf trace. The top of each picture is toward the periphery of the tumor, and they join onto each other (*X* corresponding to *X*) and also join on at their bottom to the top of Plate XLI, which shows the tumor strand.

PETIOLE A.

(Plate XLI.)

Plate XLI, from slide 590 A 2, gives a cross section of the central part of the secondary tumor in petiole *A* (Pls. XXXIX and XL), showing rapidly proliferating large cells of the tumor strand, containing spirals (the thick-walled cells). At the bottom and left the innermost elements of the wood wedges are visible. The bulk of the xylem is below, the wood cylinder being open and imperfect above.

PETIOLE B.

(Plate XLII.)

Plate XLII, from slide 590 B 13, shows a cross section of petiole *B* in the vicinity of fig. 13 (Pl. XXXVII). Above, below, and at the left are the unchanged petiolar tissues. In the center and at the left is the enlarged central leaf trace, preserving nearly its normal form (compact tissue at left of center). At the base of this, in the center of the section, is the tumor strand, radiating irregularly from which may be seen additional abnormal wood wedges. Toward the right may be seen masses of small-celled tumor tissue inclosing numerous unmodified cells of the loose parenchyma of the petiole. There are also tracheids near *X* and *X*. The leaf trace next under this one is also distorted. For a detail of the tumor strand see next plate.

PETIOLE B.

(Plate XLIII.)

Plate XLIII, from slide 590 B 10, gives the central part of a section from nearly the same level as the preceding (Pl. XLII), showing (in the center) the large soft cells of the tumor strand at the base of the primitive wood wedges of the leaf trace. The larger cells below are inclusions.

PETIOLE B.

(Plate XLIV.)

Plate XLIV, from slide 590 B 16, shows a cross section of the secondary tumor in petiole *B* at some distance from fig. 13 (Pl. XXXVII), Here the tumor strand is larger and the abnormal wood wedges are more prominent than on Plate XLII. For a detail of the tumor strand see next plate.

PETIOLE B.

(Plate XLV.)

Same as preceding plate (i. e., from slide 590 B 16), but the central part more highly magnified to show the character of the central tumor strand. The bottom of this picture corresponds to the left of the preceding. In the upper part of the strand is a whorl similar to those shown on Plates XXXIX and XL. At the right of it is an unmodified medullary ray consisting of one row of small cells and below this a modified one consisting of several rows of large soft cells. The tumor strand contains both large and small celled parenchyma.

PETIOLE B.

(Plate XLVI.)

Plate XLVI, from slide 590 B 19, shows a cross section of the middle leaf trace of petiole *B* beyond any visible swelling, i. e., somewhere near figure 19, Plate XXXVII. Here the secondary tumor is reduced to a comparatively small mass of tissue, i. e., to the tumor strand at the base of the xylem wedges, and a small mass of tissue below it. For appearance at the lower end of this petiole see the next two plates.

PETIOLE B.

(Plate XLVII.)

Plate XLVII, from slide 590 B 24, shows a cross section of petiole *B* near its base, i. e., at about the level of figure 24, Plate XXXVII. The external shape of the petiole is about normal, the upper surface of it being at the right. Only the central leaf trace is here diseased, for details of which see next plate. Section stained by Gram-eosin.

PETIOLE B.

(Plate XLVIII.)

Plate XLVIII, from slide 590 B 24, gives enlarged the middle leaf trace from the preceding plate, showing the beginning of the pseudostem (secondary tumor). In the center is a group of soft cells forming the tumor strand. This consists of mixed tissue, many of the cells being isodiametric or only slightly longer than broad, while others are more or less elongated. Above is the leaf trace slightly modified, i. e., showing in its lower part infiltration of soft cells from the tumor strand, wedging apart the spiral vessels. Below are abnormal wood wedges and connective tissue. The vessels of this part are tracheids. On the outer edge at *S* are groups of sieve tubes. To determine the origin of these abnormal wood wedges the remainder of the petiole was sectioned longitudinally, i. e., downward toward the stem. (See Pl. XLIX.)

PETIOLE B.

(Plate XLIX.)

Longitudinal section, slide 590 B_2 21, of abnormal part of leaf trace shown in Plate XLVIII. Beginning at the bottom we have: *sp*, normal spirals of the leaf trace; *tstr*, tumor strand; *scl*, normal supporting cells of the leaf trace; *tr*, abnormal tracheids developed from the tumor strand; *tp*, tumor parenchyma; *inc*, included cell, i. e., one of the large cells of the loose parenchyma of the petiole.

PETIOLE B.

(Plate L.)

Cross section of petiole B, slide 590 B 4, of Plate XXXVII, showing abnormal lignification of the walls of four of the included cells. These are large cells of the loose parenchyma of the petiole, like those shown in Plates XLII and XLIV. They have taken a deep blue stain (lignin), whereas the walls of similar cells below are pink (cellulose). Section stained with methyl green and acid fuchsin. Such abnormal lignification of parenchyma cells is not infrequent.

DAISY NO. XIII.

Whole Plant.

(Plate LI.)

This plant was inoculated on January 11, 1911, and photographed April 6, 1911, seven-eighths natural size. The inoculations were by needle pricks at *X*, *X*. The stem is swollen in the vicinity of the primary tumor. *A* and *B* are leaves bearing secondary tumors. *B* is directly over the right side of the primary tumor and 8 cm. away. The secondary growths on this leaf which have split it open in places extend outward a distance of 10 cm., making a total extension from the primary tumor of 18 cm. in 54 days. The stem between *A* and *B* is normal externally, except that at the level of figure 2 on a vertical line between the primary tumor and *B* there is a very slight swelling of the stem over the location of the tumor strand.

The internal condition between the right side of the primary tumor and *B* in a straight line is as follows: At 1, slightly thickened wood ring on the right side and a half dozen aggregated tiny spots at the junction of the wood and pith where the tissue is stained greener (best seen in thin section). At 2, the green strand under the swollen wood is more conspicuous and measures 1.5 mm. wide by 0.7 mm. thick (photographed slightly enlarged); see the lower part of this plate. At 3, the wood is not conspicuously enlarged and the strand is not visible under the hand lens. At 4, the strand again shows. Shaved tangentially between 3 and 4, we could not distinguish the tumor strand clearly by its green color.

Petiole B.

(Plate LII.)

Plate LII, from slide 589–3, gives a cross section of petiole *B* near its base, showing a secondary tumor in the central leaf trace, which is greatly enlarged and converted into a pseudostem. In its center is the tumor strand; at its right is the nearly normal xylem of the leaf trace. Radiating from the tumor strand in other directions are the abnormal wood wedges with broad bands of soft cells between them. The tumor is beginning to rupture to the surface on the left side. The cells of the petiole immediately surrounding the tumor are flattened by pressure. Gram-eosin stain. For a detail from the center of the tumor at this level, see next plate.

Longitudinal sections were made through the central leaf trace and sieve tube tissue demonstrated on the periphery of the tumor in nearly all of them.

Petiole B.

(Plate LIII.)

Plate LIII, from slide 589–12, gives the tumor strand and surrounding tissues from petiole *B* at the same level as Plate LII, enlarged to show in detail the character of the tissues. The black dots are nuclei. Sections stained with Ehrlich's acid hematoxylin. The tumor-strand has stained much redder than the surrounding tissues.

DAISY NO. XIV.

Whole Plant.

(Plate LIV.)

This plant was inoculated January 11, 1911, at *X* by needle pricks, and photographed April 6, 1911, three-fourths natural size. Leaves *A*, *B*, *C*, and *D* bear secondary tumors. The distance from the base of *A* at the top of the primary tumor to the origin of *D* is 6.5 cm. The length of the secondary tumor on *C* is 10 cm., that of the ruptured part, 6 cm. The structure of *C* in cross section is that of a stem with a complete wood cylinder, on one side of which is unchanged petiole structure (see Pl. LV). The tumor strand is sometimes in a central leaf trace and sometimes as at *B* and *D* in side traces.

At the level of fig. 2 there is a thickening of the wood and a green stain under both *B* and *C*. At 3 this is less conspicuous. At both of these levels, as seen under the microscope, the area of disturbance is not large, and both it and the green stain were confined to the inner wood next the pith.

Poured plates were made from the interior of *C* above the lower fixed portion and these yielded typical gall colonies in small numbers. On April 19, with agar subcultures from one of these colonies, five young daisy plants were inoculated. At the end of 20 days galls were forming on them at all of the inoculated places. Cultures from this colony into peptonized beef bouillon also gave the typical strings or filaments.

Petiole C.

(Plate LV.)

Plate LV, from slide 593 A 13, gives a cross section of petiole *C*, showing three of the leaf traces involved in a secondary tumor which has ruptured to the surface at the bottom and right and which shows a distinct stem structure, the wood wedges being separated in places by conspicuous plates of modified soft medullary rays (for a detail of these see Pl. LVI). Unmodified petiole tissue occurs at the left and at the top. Above the tumor strand in the lowest leaf trace is a wedge of tracheids in the outer portion of which the longer axis of the vessels extends parallel to the surface of the cut and tangential to the stem. Slide stained with methyl green and acid fuchsin.

PETIOLE C.

(Plate LVI.)

Plate LVI, from slide 593 A 22, shows a cross section of a small part of the secondary tumor in petiole *C*. At the left is a wood wedge with tracheids of normal arrangement, at the right is a wood wedge with tracheids twisted at right angles to the normal direction. Between these two is an abnormally broad medullary ray composed of soft rapidly proliferating cells, several of which contain two nuclei. In portions of such plates the ray cells (?) are twisted so that their long axis is parallel to the surface of such a cut as that here shown, i. e., like the right wood wedge. Section stained with methyl green and acid fuchsin.

PETIOLE C.

(PLATE LVII.)

Plate LVII, from slide 593 A 22, shows in cross section a woody part of the secondary tumor in petiole *C*, not far from the tumor strand. The central loosely arranged soft cells are possibly modified ray cells. They take the fuchsin stain less deeply and are much larger than the cells of the tumor strand (see next plate) which is below and at the right just outside the limits of this plate.

PETIOLE C.

(PLATE LVIII.)

Plate LVIII, from slide 593 A 22, shows a cross section of the middle part of the secondary tumor in petiole *C*. In the center is the tumor strand. This consists of small rapidly dividing cells which have stained heavily with the acid fuchsin. Surrounding this is a small portion of the pseudostem (for orientation see center of Plate LV). At *A* and *B* are modified medullary rays; at *C* and *D* are woody tissues twisted in abnormal directions. In this plate and the preceding one, *D* corresponds to *D* and the magnification is the same.

PETIOLE B.

(PLATE LIX.)

Plate LIX, from slide 593 B 2, gives a cross section of petiole *B*, showing a secondary tumor with stem structure in *X*, a lateral leaf trace. The leaf trace next below it is also slightly involved, as may be seen more clearly from Plate LX. The rest of the petiole appears to be normal.

PETIOLE B.

(PLATE LX.)

Plate LX, from slide 593 B 6, gives in cross section a portion of petiole *B*, showing the leaf trace next under *X* of Plate LIX. Here the abnormal phenomena is restricted to distortion of the bundle with the separation of a few tracheids from their fellows, the twisting of others at right angles to their normal directions, and the appearance below of wedges of soft tissues.

DAISY XVI.

WHOLE PLANT.

(Plate LXI.)

This plant was inoculated by needle pricks on January 13, 1911, and photographed April 10, 1911, nearly natural size. Primary tumor at *X* where punctured. Secondary tumors at *A*, *B*, *C*, *D*, *E*, and *F*. At *B* and *D* are stubs of leaves removed earlier for study and from the cut surface of which tumors have developed. At *C*, *E*, and *F* are remnants of leaves destroyed by the tumor. On section the base of *A* was found to have a stem structure.

In the stem, under *A* and leading up to it, was a green strand of soft tumor tissue. This was situated at the junction of wood and pith, but mostly in the wood. It continued beyond *A*, i. e., at fig. 2 on the vertical line, and still more conspicuously at 3, but less so at 4; it was visible as a small mass of soft, deep green parenchyma. There was a similar strand under *C*. On cross section this strand pushed out 0.5 mm. as though it had been under great pressure (see Pl. LXII). It contained so many chloroplasts that it was very green in comparison with the color of the wood and pith.

STEM AND LEAVES.

(Plate LXII.)

Figures *A* and *B* are enlargements of the stem between tumors: *A* gives a cross section of stem at the level of fig. 3 (Pl. LXI) under leaves *E* and *F*, showing a nearly circular strand of soft green tumor tissue with the woody cylinder conspicuously thickened on that side. The difference in color enabled us to get a photograph showing marked contrasts. ×2.

B is the same as *A*, but somewhat further enlarged and photographed obliquely to show more clearly the pushing out of the tumor strand on removal of the pressure.

These are photographs of the specimen exhibited at the meeting of the American Association for Cancer Research, Buffalo, N. Y., April 13, 1911.

Figures *C* and *E* are enlargements of the reverse side of petioles *C* and *E* (Pl. LXI), showing how these deep-seated secondary growths have split open the petiolar tissues and come to the surface. In cross section these growths appear as a flattened imperfect woody cylinder. Photographed April 10, 1911. ×3.

Enlarged Cross Section of Stem.

(Plate LXIII.)

Plate LXIII, from slide 586 A 15, gives a cross section of the stem at the level of fig. 2 (Pl. LXI), showing the tumor strand and a conspicuous enlargement of three-fourths of the woody cylinder. The strand is the dark area on the left side of the pith. The section was torn a little in mounting.

A Portion of the Tumor Strand.

(Plate LXIV.)

Plate LXIV, from slide 586 A 30, gives an outer portion of the tumor strand in cross section. It is at the same level as Plate LXV, but from another part of the strand. In the upper and left-hand part are distorted tracheids. The spiral vessels except the few mentioned below are at the right beyond this field.

A Portion of the Tumor Strand.

(Plate LXV.)

Plate LXV, from slide 586 A 30, gives the inner margin of the tumor strand in the stem, showing the stroma (pitted vessels) originating in the tumor tissue. Below this field is the pith; at *S*, *S*, are spiral vessels of the normal stem widely separated from their fellows by the intrusion of the tumor strand. The remainder of the spiral vessels lie in the direction of the arrow the width of another whole field away.

DAISY NO. XVII.

Whole Plant.

(Plate LXVI.)

This plant was inoculated January 13, 1911, by needle pricks on the stem and photographed April 10, 1911, natural size. Primary tumor at *X*, *X*, where punctured, portions of it beginning to decay. At *A*, *B*, *C*, and *D*, are leaves showing secondary tumors. *A* and *C* are affected only at the base; *B* is diseased through a length of 10 cm.; *D*, which was removed earlier for study of its tumors, has a tumor projecting from the cut surface, i. e., an outgrowth of the diseased leaf trace. The stem at *F* was fixed for sections. The tumor in *C* was also fixed. It showed stem structure at its base.

Petiole *B* showed an imperfect woody ring. The petiole was split open below at *Y* with tumor tissue protruding the same as shown in Plate LXII from plant XVI. Under *B* in the stem at *E* there was a wedge-shaped thickening of the woody ring and a distinct green tumor strand in the inner wood. Plate LXVII made from the stem at the level of *F* shows a smaller tumor strand passing toward *D*.

CROSS SECTION OF STEM.

(Plate LXVII.)

Plate LXVII, from slide 639 A 19, gives a cross section of the stem at one end of *F* (see preceding plate), showing a small tumor strand passing to leaf *D*. This is in the inner wood jutting into the pith in that portion of the woody ring (lower part at *X*) which is thickened a little. This thickening was more conspicuous a half centimeter farther down, i. e., under *B*. For a detail of this strand see Plate LXVIII. The diameter of this section is 7.5 mm. The dark places in the bark are normal.

TUMOR STRAND IN STEM.

(Plate LXVIII.)

Plate LXVIII, from slide 639 A 20, gives a detail from the same level as Plate LXVII, showing (in the center) the tumor strand with tracheids developing in it. This is the more interesting because the vessels immediately above the strand (all shown in this photograph) are spirals. Pith below. Both this section and the preceding were stained with methyl green and acid fuchsin.

TUMOR STRAND IN STEM.

(Plate LXIX.)

The same as the preceding but cut from the other end of the stem at the level of *F*, slide 639 AA 21. Pith below, wood above, tumor strand in the center. Section torn a little at the bottom.

The vessels of the wood immediately above this strand are spirals. Just below the strand are four spirals wedged away from their fellows by the growth of the strand. There is also one crushed spiral nearer the strand and two or three displaced ones at the left. No tracheids are visible in it or near it.

PETIOLE C, SHOWING TUMOR STRAND.

(Plate LXX.)

Base of petiole *C*, slide 639 B 10, showing the tumor strand in longitudinal section. Vessels and other tissue lie to either side.

TUMOR TISSUE FROM PETIOLE C.

(Plate LXXI.)

Tumor tissue from the base of petiole *C*, slide 639 B 5, showing cells with 2 and 3 nuclei. On the right are tracheids mingled with tumor cells. The elongated cells at the left are tumor cells cut parallel to their longer axis. There are probably two types of tumor cells in this section. Stained with methyl green and acid fuchsin.

INFILTRATION OF TUMOR TISSUE IN PETIOLE C.

(Plate LXXII.)

Margin of a secondary unruptured tumor in petiole *C*, slide 639 B 9, showing infiltration of the tumor cells into the coarse-celled tissue on the periphery of the petiole. The tumor is at the left, the parenchyma of the petiole at the right. In the upper part, at the extreme right, the epidermis *E* is visible. Outer portion of the petiole curved by the internal pressure.

DAISY No. XVIII.

WHOLE PLANT.

(Plate LXXIII.)

This plant was inoculated January 13, 1911, by needle pricks at *X*, *X*, where the primary tumor developed, and photographed April 10, 1911, nearly natural size. Secondary tumors developed on leaves *A* and *B*. The tumor on *A* is in a marginal leaf trace. The tumor strand of *B* is in the central leaf trace and six tumors developing from it have reached the surface, the remotest one being 9.5 cm. from the stem. Both branches of this leaf (*X* and *Y*) are diseased. The insertion of this leaf is 2 cm. from the top of the primary tumor at *T*.

Immediately above the primary tumor and under *B*, cross sections of the fresh stem showed the woody cylinder thickened a little on that side. The inner angle of the xylem wedges next the pith was greenish, but there was no conspicuous strand. Under the compound microscope two tumor strands are visible, however, in stained cross sections of this stem.

PETIOLE A.

(Plate LXXIV.)

Plate LXXIV, from slide 635 B 9, is a longitudinal section of petiole *A*, showing the tumor strand. This plate at its bottom joins on to the top of the next plate.

Petiole A.

(Plate LXXV.)

Plate LXXV, from slide 635 B 9, is a continuation of Plate LXXIV, showing the tumor strand expanding at bottom into a small tumor. For a continuation of this see next plate.

Petiole A.

(Plate LXXVI.)

The top of this plate, from slide 635 B 11, joins on to the bottom of the preceding plate, but the magnification is somewhat greater. The bulk of the plate (all of the center) is occupied by the tumor in which may be seen four centers of active proliferation.

DAISY NO. XIX.

Whole Plant.

(Plate LXXVII.)

This plant was inoculated by needle pricks at *X*, *X* on January 13, 1911, and photographed April 15, 1911, three-fourths natural size. Diameter of stem at *Z*, 12 mm. Distance from the primary tumor to the insertion of *B*, 3.5 cm. and length of the secondary tumor in *B*, 9 cm. Stem structure at *S*, *S*. Portions of *A* and *B* were fixed in Carnoy's solution and also the stem to either side of 3. The stem between *A* and *B* was normal on the surface except for a slight swelling on the right side at the level of 3. Here on cross section a small green tumor strand in the wood was visible under the hand lens, but not in this manner at 1, 2, or 4.

Cross Section of Stem.

(Plate LXXVIII.)

Plate LXXVIII, from slide 595 A_1 8, gives a cross section of the right side of the stem not far from figure 3 of the preceding plate, showing a small tumor strand at *X* where the wood is slightly thickened. The remainder of the stem is normal. The bark was torn a little in mounting, and the outer portion of the pith was shriveled by the fixative. Section stained with methyl green and acid fuchsin. For appearance of the tumor strand more highly magnified and a little farther down (or up), see next plate.

Cross Section of Stem.

(Plate LXXIX.)

Plate LXXIX from slide 595 A_2 1 gives a cross section of the stem a few millimeters away from that shown on Plate LXXVIII and more highly magnified, showing a conspicuous tumor strand in the inner wood near the pith. This is composed of large, soft, thin-walled cells, easily differentiated from the surrounding cells not only by their *form* but by their behavior toward stains, i. e., the surrounding cells are blue while these are red. Stain: methyl green and acid fuchsin.

PETIOLE A.

(Plate LXXX.)

Plate LXXX from slide 634 D 15 gives in longitudinal section an infected leaf trace at the base of petiole A, showing a conspicuous tumor strand with vessels to either side—spirals at the right. At X are cells of the tumor strand undergoing change into tracheids. Stained with methyl green and acid fuchsin. See plate IV for a longitudinal section through a normal leaf trace.

PETIOLE A.

(Plate LXXXI.)

Plate LXXXI from slide 634 A 4 shows a longitudinal section of petiole *A*, like Plate LXXX but farther up the leaf, i. e., the section was made between *Y* and *Y′*. To the left are nearly unchanged vessels of the leaf trace (stained blue in the section); to the right is the large-celled parenchyma of the ground tissue of the petiole. Between the two in the region of the spiral vessels is the tumor strand. Stain: Methyl green and acid fuchsin. Tracheids at *T′*, spirals at *S*, *S*, cambium at *C*, and phloem at *P*.

PETIOLE A.

(Plate LXXXII.)

Plate LXXXII, from slide 634 D 4, gives a longitudinal section through petiole *A* at the level of the unruptured secondary tumor *Y*, showing the stroma of the tumor, i. e., the development of tracheids in the tumor tissue. In the section the tracheids are blue and the tumor cells red. The normal direction of the tracheids is right and left, and in healthy leaf traces and also in the normal parts of diseased ones they are straight and parallel, as shown in the left-hand part of Plate LXXXI. In this section no wood fibers accompany the tracheids.

PETIOLE B.

(Plate LXXXIII.)

Plate LXXXIII, from slide 595 B_2 5, gives a cross section of petiole *B* to show its conversion into a stem under the influence of the tumor strand. The actual diameter of the section is 9 mm. The only unchanged parts of the petiole are the wings *W*, *W*, and a little coarse-celled parenchyma at the left. There is a slight gap in the woody cylinder (bottom part above *W*), which is bridged over by tracheids which have grown at right angles to their normal direction. On the right side of the rapidly proliferating soft central mass of cells (tumor strand) are four whorls of tracheids inclosing soft cells (see next plate). The large cells to the right of these are portions of the petiole parenchyma surrounded by the tumor tissue and more or less modified by its presence. The dark spot in the upper part of this mass is a cell of the same type in the walls of which lignin has been deposited abnormally. Section stained with methyl green and acid fuchsin.

WHORLS FROM PETIOLE B.

(Plate LXXXIV.)

Plate LXXXIV, from slide 595 B_2 8, gives a cross section of a small portion of petiole *B* at nearly the same level as Plate LXXXIII, showing the character of two of the tracheal whorls on the border of the tumor strand, which lies in the direction of the arrow. One of the whorls contains large cells and the other small ones. Section stained with methyl green and acid fuchsin.

BASE OF PETIOLE B.

(Plate LXXXV.)

Plate LXXXV, from slide 634 B 5, shows a cross section of the extreme base of petiole *B*. Seminormal wood wedges are at the left; abnormal ones at the right; tumor strand in the center. In the middle and on the left margin of this are crushed spiral vessels. Stained with methyl green and acid fuchsin.

DAISY NO. XX.

WHOLE PLANT.

(Plate LXXXVI.)

This plant was inoculated January 13, 1911, by needle pricks at *X*, *X*, and photographed April 17, 1911, nearly natural size. Primary tumor at *XX*, beginning to decay; secondary tumors on leaves *A*, *B*, *C*, *D*, and *E*. Leaf *A* has shriveled nearly to its base, which is much swollen. Leaf *C*, which bore secondary tumors, was removed earlier for study and now bears a tumor on its cut curface. On *D* the tumor extends as far as *Y*. The distance from *Y* to insertion of *D* is 12 cm. The distance from *Z* to insertion of *E* is 10.5 cm., and from this point to the top of the primary tumor is an additional 2.5 cm.

The dissection notes are as follows: At 1, immediately under *B* (lower figure), the cross section shows a soft green tumor strand at the junction of wood and pith, with slight enlargement of the wood on that side. The wood is also enlarged under *D*, and a tumor strand also apparently is present here, but not conspicuous; later (Pl. LXXXVII) it was demonstrated conclusively under the microscope. At 2 and 3 there was no distinct enlargement of the wood. Split longitudinally between 1 and 2 the stem showed to the naked eye a green strand narrowing upward and running out near 2.

Material was fixed from *D* and *E* and from the stem below *D*, all of which showed typical invasion.

CROSS SECTION OF STEM.

(Plate LXXXVII.)

Plate LXXXVII, from slide 632 C 3, gives a cross section of the stem below petiole *D*, showing a small tumor strand in the center. Below is pith; above are the spiral vessels of the inner wood, with medullary rays between them. At *X*, *X*, are two spiral vessels separated from their fellows and crushed.

PETIOLE D.

(Plates LXXXVIII to XC.)

Plate LXXXVIII, from slide 632 D 8, gives a longitudinal section of petiole *D*, showing the general relations of the small central neoplasm to the petiolar structure. A detail from the upper end of this tumor is shown on Plate LXXXIX, and a section near the periphery of the same tumor on Plate XC. Here the spirals are twisted and wedged apart. Tracheids occur to either side beyond the spirals and also in the tumor tissue at *X*. The nuclei, which appear to be in the spirals, are in tumor tissue under them.

PETIOLE D.

(Plate XCI.)

Plate XCI, from slide 632 D 10, gives a longitudinal section of petiole *D*, showing the appearance of one end of a small unruptured tumor developing from the tumor strand. The other end of the same tumor is shown in plate XCII. The two photographs together cover about three-fourths of the tumor.

PETIOLE D.

(Plate XCII.)

Plate XCII, from slide 632 D 10, shows a longitudinal section of petiole *D*. It was photographed from the other end of the tumor shown in the preceding plate. The wedged-off tracheids are at the top. The normal tracheids and the spirals (somewhat displaced and crushed) are at the bottom. For continuation of the tumor strand see next plate (XCIII).

PETIOLE D.

(Plate XCIII.)

Plate XCIII, from slide 632 D 10, gives a longitudinal section of petiole *D*, taken one field away from the preceding plate (XCII), showing the continuation of the tumor strand (center) with vessels to either side.

DAISY NO. —.

MARGIN OF TUMOR IN PETIOLE.

(Plate XCIV.)

This petiole is from one of the plants inoculated January 13, 1911. It was fixed March 6, 1911. This plate, XCIV, from slide 574 A 4, shows the extreme margin of an unruptured secondary tumor, surrounded by and inclosing (*P*, *P*) normal large cells of the petiolar parenchyma. Rather large pieces of the material were fixed in Flemming's fixative *A* for 24 hours, then soaked 24 hours in a hardening fluid consisting of water 99, glacial acetic acid 0.7, and chromic acid 0.3 and washed in running water for 24 hours. The section was stained with methyl green and acid fuchsin. It belongs in this series, but no record was made of the plant number. At *T* is a bit of the stroma (a group of tracheids).

DAISY NO. XXXI.

FOLIAGE.

(Plates XCV to XCVII.)

Plate XCV shows the top of a plant inoculated April 26, 1911, in the leaves only by means of single needle pricks. It was photographed June 2, 1911, i. e., at the end of 37 days. Sections of two of these tumors for comparison with secondary tumors in the leaves follow as Plates XCVI and XCVII. The structure consists of a mixture of tracheids with soft-celled tumor tissue. There is no such differentiation of parts as shown in the secondary leaf tumors., i. e., no distinct stem structure.

HOP ON TOBACCO.

PITH OF STEM, CAMBIUM, ETC.

(Plates XCVIII to CIII.)

An effort was made to determine, by inoculation into young stems of rapidly growing tobacco plants, just which tissues were stimulated to proliferate. While the results from these inoculations are not entirely conclusive, some very interesting phenomena were observed. It was shown, for instance, in material three weeks inoculated, that there was no proliferation along the needle track *in the pith* (Pl. XCVIII), but an area of proliferation developed in the vicinity of the cambium (Pl. XCIX). Small tumors arose also on the margins of the needle wounds at various levels. Plate C shows one at the mouth of the needle wound and Plate CI shows one about half way from the lips of the wound to the cambium line. Both of these small tumors are well provided with tracheids (*tr*), although they are both growing from the level of the bark parenchyma where no tracheids are normally present. The question here is whether the nodules were developed in place, i. e., out of infected parenchyma or from deeper cells whose progeny have come to the surface. A study of the whole series of sections would seem to indicate the former surmise as the correct one. The presence of tracheids and sieve tubes, x, also indicates this. Further studies will be made. In Plates C and CI the needle wound is at the right and the bark parenchyma at the left.

Perhaps the most interesting feature brought out by these inoculations relates to the tumor strand. In all of the daisy inoculations we have seen the tumor strand select the protoxylem region of the stem as the line of least resistance to its movements. In one of the tobacco plants a strand of small-celled tissue originating in the proliferations from one of the infected needle wounds passes through the middle of the coarse-celled bark parenchyma parallel to the surface of the stem, as shown in Plates CII and CIII, which join onto each other, x corresponding to x. The arrow indicates the direction of the surface of the stem, which is about 12 cell-layers away. The phloem lies at about an equal distance away from this strand in the opposite direction. This strand can be traced only on slides 23, 24, and 25. It ceases a little beyond the top of the first plate. Above and below these sections is the ordinary bark parenchyma. The strand is sparingly provided with tracheids, the smallest group being at x^1. The needle track lies just below the lower tracheids shown in Plate CIII.

DAISY TUMOR.

Chromium Reaction.

(Plate CIV.)

Figure 1 of Plate CIV shows the effect of five minutes' exposure to a hot saturated solution of potassium bichromate. The black pieces are slices of a young tumor; the pale ones are longitudinal sections and cross sections of normal young stems of the same plant.

Figure 2, right-hand side, shows the appearance of slices of young tumors exposed for five minutes to a hot saturated solution of potassium chromate. The left-hand colorless sections are pieces from the same tumor which were extracted in hot ethyl alcohol for a few minutes before exposing to the hot bath of potassium chromate.

Cytological Studies.

(Plates CV, CVI, and CVII.)

Plate CV shows the first results of an attempt to photograph *Bact. tumefaciens* within the cells of the tumor. Lantern slides of these figures were exhibited at Philadelphia, April 4, 1912, before the American Association for Cancer Research. The nuclei are unstained, and counterstained with eosine. Rods and Y's are visible, also many negligible granules. The figures 1, 1 denote different levels in the same cell. The middle figure (branched rod) in the top row of Plate CVII is also from this field. In the lower right-hand figure a Y-body lies on the upper part of the nucleus—outside of it, however.

Plate CVI shows various levels in a single cell, which is nearly or quite free from precipitates and contains numerous bacteria (deep blue-black rods on a colorless ground). Its faint nucleus (*N*) may be seen at the bottom of the left-hand figure of the middle row. Above it in the upper left-hand part of the figure is the conspicuous nucleus of a cell which is free from infection, or nearly so. Owing to the slight penetration of the Zeiss oil immersion lens (3 mm. 1.30 n. a.) eight photomicrographs were made at different levels in this field so as to give as clear a picture as possible. The figures 1, 1; 2, 2; etc., denote corresponding places in the photographs. The bulbous ends of some of the rods, e. g., 2, are illusions due to the fact that only a portion of the rod is in sharp focus. The cell walls are unstained and invisible except with a very narrow pencil of rays.

Plate CVII shows additional rods and branched forms, and absence of these bodies in the nucleus. The numbered places represent slightly different levels in the same cells. The bacteria lie in such irregular positions that it is impossible to have many of them sharply defined at any one focus, e. g., in the lower part of the right-hand figure of the upper row are three rods in a chain, but the lower one is entirely out of focus. The one marked 4 in the lower figure shows distinct branching but had to be made a little vague to get 3. So, also, in the upper left-hand corner of the second figure from the bottom, 5 is distinctly branched but had to be thrown out to get portions of the three rods marked 6. The tumors used for these sections were impregnated in bulk and afterwards sectioned. In their preparation suitable material was sliced from the tumors and put for 24 hours into water containing 5 per cent gold chloride. It was then transferred to 0.25 per cent formic acid and kept in the dark for 24 hours (modification of Löwit's method for nerve fibers), after which it was washed, dehydrated, and embedded in paraffin in the usual way.

To bring out cell walls, protoplasm, and nucleus, some of the sections were subsequently stained on the slide with eosine, a faint stain proving most satisfactory.

(Plates CVIII and CIX.)

These two plates were made from photomicrographs of the 5μ thick section already referred to, which was stained by Gram, and washed in amyl alcohol until very pale. They are introduced to show lenticular chloroplasts which when seen edge-on might be confused with bacteria. The upper figure of Plate CVIII also shows a nucleus in amitotic division (see fig. 1 in text). The dark spot in the center of Plate CIX is a nucleus out of focus. To bring that into sharp focus threw the chloroplasts entirely out of focus.

ANALOGIES.

The higher plants are much simpler in structure and function than the higher animals and any comparison of the diseases of one with the other must take these facts into account. The plant is much closer to the soil than the animal, i. e., to the inorganic world.

Neither may the higher plants be regarded, like the higher animals, as units. They are rather to be regarded as congeries of such units, one or more of which may be destroyed without injury to the rest. A peach tree, for example, may be split longitudinally and, if care be exercised, the two halves will continue to live as separate trees, the circulation of the two parts being distinct because the movement of fluids, foods, etc., is up and down rather than sidewise. This is illustrated by the fact that if we cut all of the feeding roots on one side of a tree, the other side is not immediately injured, and, if we introduce into the circulation on one side of the trunk some readily diffusible substance, it quickly passes to the top of the tree on that side, but moves around the trunk to the other side only very slowly. If these overgrowths are cancers we might, therefore, expect what we find, namely, that the tree as a whole is less injured by such growths than would be an animal with a unitary structure and a rapid general blood circulation.

For similar reasons structural comparisons of the higher plants and animals is difficult. While such plants and animals are fundamentally alike in that both are composed of living cells multiplying in the same manner, capable of secretion and excretion, and having divided labors but united into a harmonious whole, yet when we come to compare their anatomy and the diverse ways in which the same physiological ends are accomplished, many difficulties arise. There is, for instance, in the plant no muscular system, no nervous system, and nothing corresponding to the complex digestive apparatus of the higher animals. The reproductive apparatus occupies a smaller space in plants and is temporary. Also, to a much greater extent than in animals, the cells which secrete special products are distributed among other cells, rather than grouped together into special organs.

We might, therefore, expect to find in a plant cancer, if such a disease exists, both simplification, and combination of traits which in the animal appear to be peculiar to the tumors of special tissues.

When the writer compared crown-gall to sarcoma it was with such mental reservations as grow out of these differences. In the connective tissue of plants there is no interstitial substance, and therefore we could not expect to find it in a plant tumor derived from such tissues. Their general appearance, therefore, is more like a nontypical epithelioma or carcinoma; so also is the marked cell reaction in their vicinity, viz, increase of wood elements; and the structure of their secondary tumors. But, inasmuch as the round cells appear to be sometimes derivatives from the mother cells of medullary rays and show all gradations from actively vegetative unripe cells into well-developed ray cells forming overgrown medullary plates, and at other times are descendants of certain cells of the bark parenchyma, we may perhaps still regard them as resembling sarcomas. They are also like the latter in their predilection for young plants and the softer, more rapidly growing tissues of older plants, as well as in the luxuriant anaplastic character of their proliferations.

Another difficulty, however, has arisen. At that time I regarded the stroma of such tumors as ingrowths developed from the surrounding tissues under the stimulus of the tumor cells. Recent experiments undertaken to settle this point seem to indicate that the vessels (tracheids and sieve tubes) in part, at least, originate in the tumor directly from tumor cells; i. e., that the tumor-strand is a complex body containing some cells capable of originating vessels and others of a purely vegetative unripe sort.

The experiments leading to this conclusion were shallow pricks into stems. Here the needle did not reach to the phloem, much less to the still deeper cambium, and yet both sieve tubes and tracheids developed in these shallow tumors in tissue which never normally produces them.

In other words, if we have not misread the evidence, under the stimulus of this organism, certain cells of the bark parenchyma (upper part of Plate I) lose their specific features and become small rapidly proliferating purely vegetative (unripe) cells, while others develop tracheids and sieve tubes; i. e., tissues normally developed only by the deeper cambium. A study in serial section of small tumors thus produced shows an abundant production of vessels in the absence of any wounding of the deeper cambium and in stems where no cork cambium has yet developed. The parenchyma cells of such tumors, as shown by their form, their size, and their behavior toward stains are purely vegetative and quite distinct from the matrix of bark parenchyma cells in which they lie and from some of which they have developed. This ability of cells of the bark parenchyma, which are as well differentiated as those shown in Plate I, to produce undifferentiated blastomous cells, some of which are capable of developing xylem and phloem, was not what we expected to find, but is clearly what the shallow inoculations seem to establish, and this conforms very well to a statement made in Bulletin 213, viz, "It is not yet beyond dispute that a cell mother of one kind can never give rise to a cell of another kind when a changed stimulus is applied."

In some cases a portion of the stroma seems to grow into the edges of the tumor from the surrounding tissue and the subject is so interesting that further studies will be made.

The tumor development is not due to diminished external resistance but to an increased internal stimulus central within certain infected cells. That this stimulus can act at a distance—i. e., is not confined strictly to the infected cells—seems probable both from the macroscopic appearance of stems penetrated by the tumor strand and from the findings in the sections made from the material treated with gold chloride. The reader is referred especially to the wood overgrowths shown on Plates XXV, LXII (Figure A), and LXIII. Here the tumor strand containing the bacteria lies in previously formed dormant tissue at the base of the wood wedges next to the pith far away from the cambium which originates new wood. Yet the wood on that side of the stem is enormously overgrown. Since we have no reason to think the cambium infected by the tumor-producing bacteria because it has developed normally and is only different from that on the other side of the stem in having laid down an excessive volume of wood, we can only account for this overgrowth by postulating action at a distance, exerted by the tumor strand. We might assume either a weak toxic action on the cambium exerted by substances diffused from the infected cells of the tumor strand, or only that the growth has been induced by the stimulus of an extra supply of water and other foods drawn into this part of the stem by the presence of the rapidly growing soft tissue of the strand. In that case, however, it is hard to account for the fact that the bark is not involved in this overgrowth. The amount of overgrowth in the wood seems to depend on the size of the tumor strand. Compare in this particular the plates already referred to with Plates LXVII and LXXVIII, in which the tumor strand is small.

Reference has been made (p. 12) to the morphological similarities between this disease and malignant growths in animals. Here some of the physiological resemblances may be mentioned:

(1) The disease is not an abscess, but an abnormal organization process.

(2) The growth is extra-physiological and detrimental to the plant.

(3) The growth tends to return after excision.

(4) It tends to develop in wounds or irritated places.

(5) There are grades of virulence.

(6) The structure of the gall is looser than that of normal tissues, and decay often sets in early, forming open wounds subject to secondary infections.

(7) The nuclei are hyperchromatic and often stain deepest on the edges of the growth, as in cancer.

(8) There occur in excess in the morbid tissues certain cell products (chemical substances) serving to distinguish the anaplastic cells from normal meristematic or embryonic tissues.

(9) In some cases increased resistance has been developed by inoculations.

Adami in his Principles of Pathology (Vol. I, p. 651) defines neoplastic tumors as follows:

"It is this autonomy, this growth independent of function and of either present or future needs of the organism in which they occur and from which they gain their nourishment, independent also of obvious stimulation from without, that distinguishes the neoplasms proper from all other forms of tissue growth."

From the same source (p. 652) several other pertinent definitions may be quoted. Wishing to include teratomas, he says:

"We prefer C. P. White's statement that 'a tumor proper is a mass of cells, tissues, or organs resembling those normally present, but arranged atypically. It grows at the expense of the organism without at the same time subserving any useful function.' Von Rindfleisch characterizes them as a 'localized degenerative excess of growth'; i. e., the very excess of growth is regarded as in itself a degeneration; Birch-Hirschfeld, as originating spontaneously, becoming separate from the physiological tissues in their physiological and functional relationships, as developing from the cells of the body, and possessing progressive growth; Ribbert, as 'self-confined, dependent upon the organism for their nourishment, but otherwise largely if not quite independent, corresponding more or less but never absolutely with the tissues of the natural body, and presenting no definite limit, to their growth.' Lubarsch's definition is closely allied: 'Under tumor proper we have to understand those growths of apparently independent origin which histologically correspond in structure more or less completely with the matrix from which they originate, but in form are atypical; which further, in spite of their organic connection with that matrix, and in subjection apparently to laws of their own, pursue an independent existence which is not, or only exceptionally, of advantage to the organism as a whole.'"

Excluding the hypotheses, these definitions apply strictly to the growths here described. Indeed, in terms of morphology and physiology, excluding teratomas, it would be difficult to frame a definition of tumors as a whole which would exclude crown galls. The only way they can be excluded is to say that they occur on plants and are of known origin, whereas the others occur on animals and are of unknown origin, and that would be begging the question.

RÉSUMÉ.

The principal facts brought to light during this study and our earlier studies may be summarized as follows:

(1) Crown galls occur on a great variety of plants, but not always on the crown; any part of the root or shoot is liable to attack.

(2) They are injurious to the plant in varying degrees, depending on the species, on the parts attacked, on the size and vigor of the individual, etc. They are most injurious to young and rapidly growing plants.

(3) Young, well-nourished, rapidly-growing tissues take the disease more readily than old or slow-growing ones.

(4) They are all of parasitic origin, unless the one on the beet studied by Jensen, Reinelt, and Spisar, in Europe, should prove an exception. We found it difficult to obtain virulent cultures from old galls occurring naturally on the sugar beet, but did finally obtain slow-growing tumors from certain colonies (Bul. 213, Pl. XXXVI).

(5) The structure of crown gall is unlike that of club-root of cabbage, which is a hypertrophy rather than a hyperplasia.

(6) We have isolated the parasite from 24 species belonging to 14 families of phanerogams. Some species have resisted infection.

(7) These galls are due to schizomycetes, either to one polymorphic species, or to several closely related species. Further studies are necessary. For notes on the morphology and biology of these isolations see Bulletin 213, page 127.

(8) The infectious nature of the organism isolated has been proved by hundreds of inoculations and its ability to produce galls on other plants than the one from which it was isolated by many cross inoculations. (Bul. 213, p. 133.)

(9) The parasite has been shown to occur not only in the primary tumor, but also in the secondary tumors and in the connecting tumor strand. Once only in the latter.

(10) Various noninfectious saprophytes also occur in crown galls especially when old, viz, white, green-fluorescent, yellow, and pink bacteria; fungi; mites; myxomycetes, etc. Other infectious organisms may also gain an entrance, viz, the pear-blight bacillus, the fungi of root rot, and borers which, especially in the peach, seem to prefer the soft tissues of the galls.

(11) The parasite has been grown in pure culture on a variety of media and its morphology and cultural peculiarities determined.

(12) When taken from young agar or bouillon cultures, *Bact. tumefaciens* is a short rod with rounded ends, dividing by fission and motile by means of a polar flagellum (sometimes 2 or 3 are present). Short chains and filaments occur. Under unfavorable conditions branched forms (involution bodies) are common. It stains readily, but not by Gram. It is not acid-fast. It is not distinctly capsulate and does not produce spores. For additional details see Bulletin 213.

(13) It grows readily on a variety of the common culture-media, but nearly always it is slow to start off when cultivated directly from the tumors. It forms small, white, wet-glistening, circular, flat colonies on agar plates and is also white on other media. It does not liquefy gelatin nor are its gelatin colonies characteristic. The organism is aerobic in its tendencies. It forms stringy filamentous growths in bouillon. The coagulation of milk is delayed. It blues litmus milk. It does not reduce nitrates nor grow well in Cohn's solution (daisy). It is sensitive to heat, to dry air, to acids, and to germicides. For additional notes see Bulletin 213.

(14) The organism slowly loses virulence when grown on culture-media. We believe that many of the bacteria also lose virulence within the tumor, because not all colonies growing typically on agar poured plates, and in other media, are infectious.

(15) Some of its biochemical properties are now known, to wit, the production from grape sugar of an acid which seems to play an important rôle in the tumor development. Alcohol also occurs.

(16) It has also been stained within the tissues of the tumor and its form and locus therein determined.

(17) The morphology and biological peculiarities of the tumor growth have been studied.

(18) The tissues of the gall multiply excessively and in opposition to the best interests of the plant.

(19) The galled tissue, which is often of a soft, fleshy nature, is much subject to decay. It is not usually corked over, and this absence of a protective surface allows the ready entrance of water and of other parasites.

(20) The tumor originates in meristem, usually in the cambium region. It may perish within a few months or continue to grow (parts of it) for years.

(21) The tumor consists, or may consist, not only of parenchyma cells but also of vessels and fibers, i. e., it is provided with a stroma which develops gradually as the tumor grows. A proliferating tumor usually contains not only meristem but pitted vessels and sieve tubes; it may also contain wood fibers, but does not always.

(22) The tumor sends out roots (tumor strands) into the normal tissues. These may extend for some distance from the tumor—how far is not known. These strands consist of meristem capable of originating medullary rays, tracheids, and sieve tubes. In the daisy the strand passes through the protoxylem region of the stem. It is rich in chloroplasts. It usually takes a deeper stain than the surrounding tissues, from which it is sharply delimited. A considerable part of it consists of unripe, actively vegetating cells.

(23) In the daisy the infiltrations are not through the vessels, but between them in a tissue offering little resistance to intrusion, i. e., the region occupied by the thin-walled, delicate spiral vessels.

(24) In the substance of these deep-lying strands secondary tumors develop. These gradually rupture their way to the surface.

(25) The secondary tumors tend to take on the structure of the primary tumor, e. g., if the latter is in the stem and the former in a leaf, the secondary tumor shows a stem structure.

(26) The stimulus to tumor development comes from the presence of the parasite within certain of the cells. Apparently it is not in all. The organism has not been observed with certainty outside of the cells, either in the vessels or the intercellular spaces, nor is it abundant in the cells. Usually copious inoculations have to be made to insure cultures.

(27) Under the microscope it can not be made out in unstained sections with any certainty, and most bacterial stains also fail to differentiate it in the tissues. (Histological Pls. VII to CIII.) It is best observed in tissues impregnated with chloride of gold. (Pls. CV to CVII.)

(28) When subjected to unfavorable conditions in cultures the parasite develops involution forms consisting of club-shaped, Y-shaped, and variously branched bodies. The same bodies occur within the cells of the tumor, making it reasonable to infer that the parasite is there exposed to similar unfavorable conditions.

(29) These involution forms may be produced at will by the addition of dilute acid to young cultures. The abnormal forms (Y's, etc.) thus produced either refuse to grow when sown in agar plates or develop colonies slowly. The same results are obtained very often on making poured plates from the tumors, viz, either no colonies appear or slowly developing ones, but subcultures from these slowly developing colonies grow promptly. Sometimes also from the tumor one gets the organism promptly on agar poured plates (third

day). In the delayed cases the mere change from tumor tissue to culture media is not the cause of the delay.

(30) By repeated inoculations through a series of years we obtained (Bul. 213, p. 177) plants which appeared to be more resistant to the disease than check plants, but by subsequent inoculations on descendants of these plants we obtained numerous well-developed primary and secondary tumors, so that the resistance which we obtained must be regarded either (*a*) as of a fugitive nature, or (*b*) as of a low grade easily overcome by a more virulent strain of the parasite. That the cultures used for these subsequent inoculations came from a more virulent strain may be assumed, we think, both because they were plated from a tumor which appeared on one of our most resistant plants, and because the cultures tried on a great number of plants (including those described in this bulletin) produced primary tumors very quickly and showed an unusually strong tendency to develop secondary tumors.

(31) The relation between the host and the parasite may be regarded as a symbiosis in which the parasite has the advantage.

(32) The bacterium is a soil organism and planters should aim to keep their lands free from it by refusing to plant infected stock.

(33) Nurserymen should plant on uninfected land and carefully avoid heeling good stock into soil which has previously received infected plants. Nurserymen have been largely responsible for the dissemination of this disease.

(34) The organism is a wound parasite. Its entrance is favored by careless grafting (Hedgcock) and by the presence of borers, nematodes, etc.

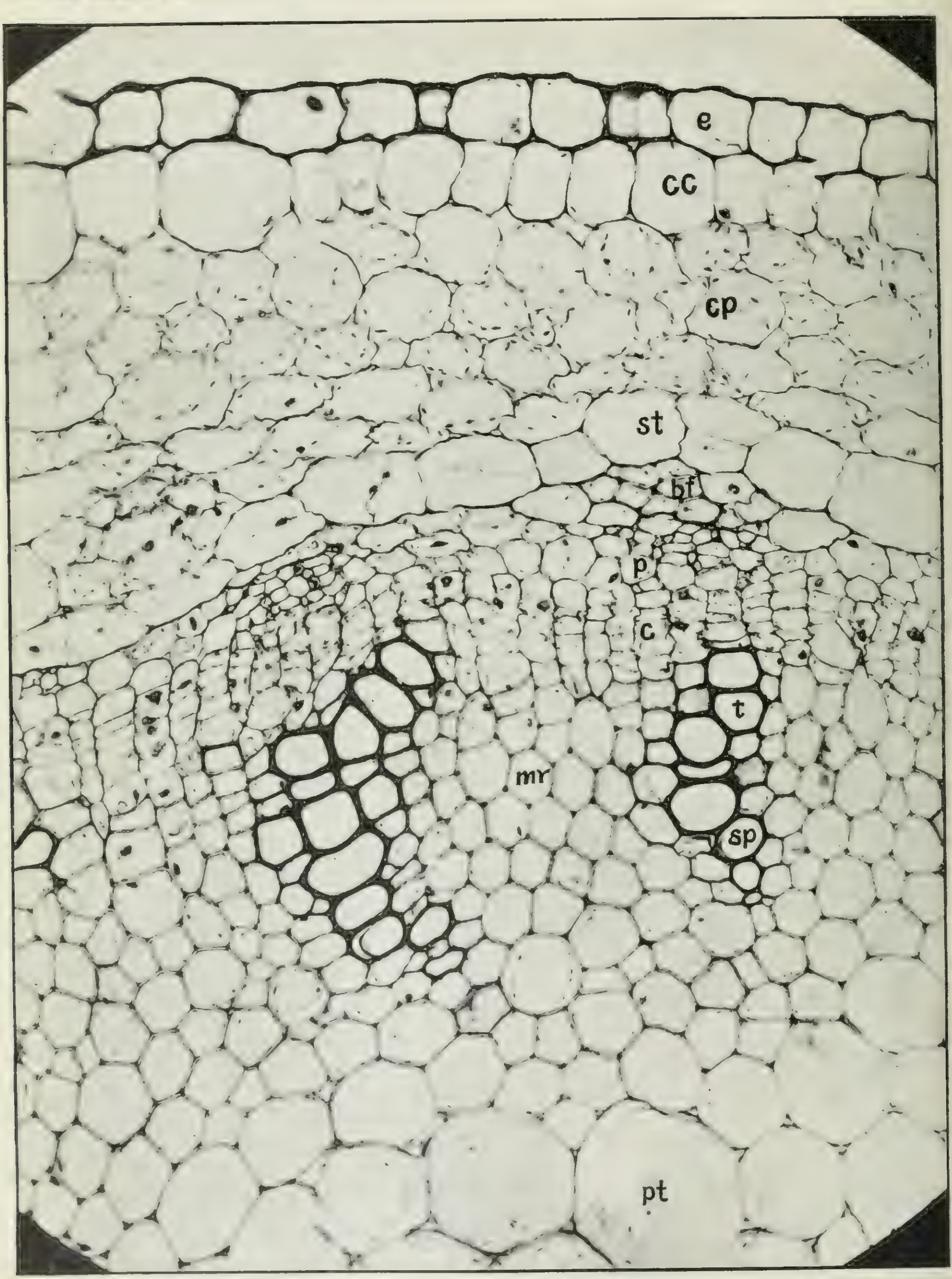
(35) These galls occur on the roots of Legumes and have been mistaken for the nitrogen root nodules.

(36) The development of this disease is regarded as closely paralleling what takes place in cancer of men and animals.

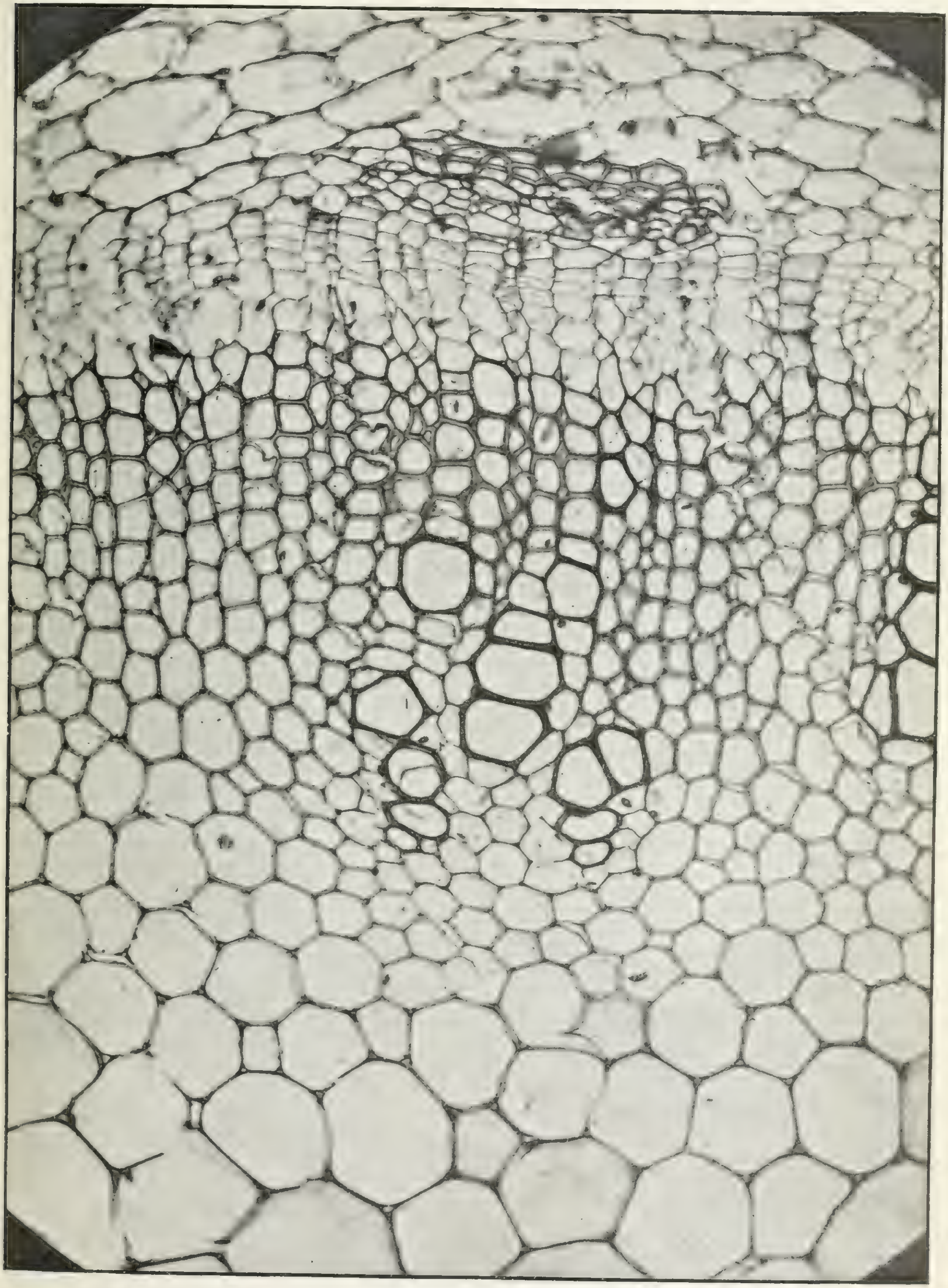
(37) There are no true metastases in crown gall, but this does not, to our mind, militate against the comparison, for whether a cancer shall be propagated by floating islands of tissue, or only by tumor-strands, appears to be a secondary matter depending on the character of the host tissues rather than on the nature of the disease. The essential element is the internal stimulus to cell division.

(38) Nothing in this bulletin should be construed as indicating that we think the organism causing crown galls is able also to cause human cancer, but only that we believe the latter due to a cell parasite of some sort, and offer the preceding pages in support of this contention.

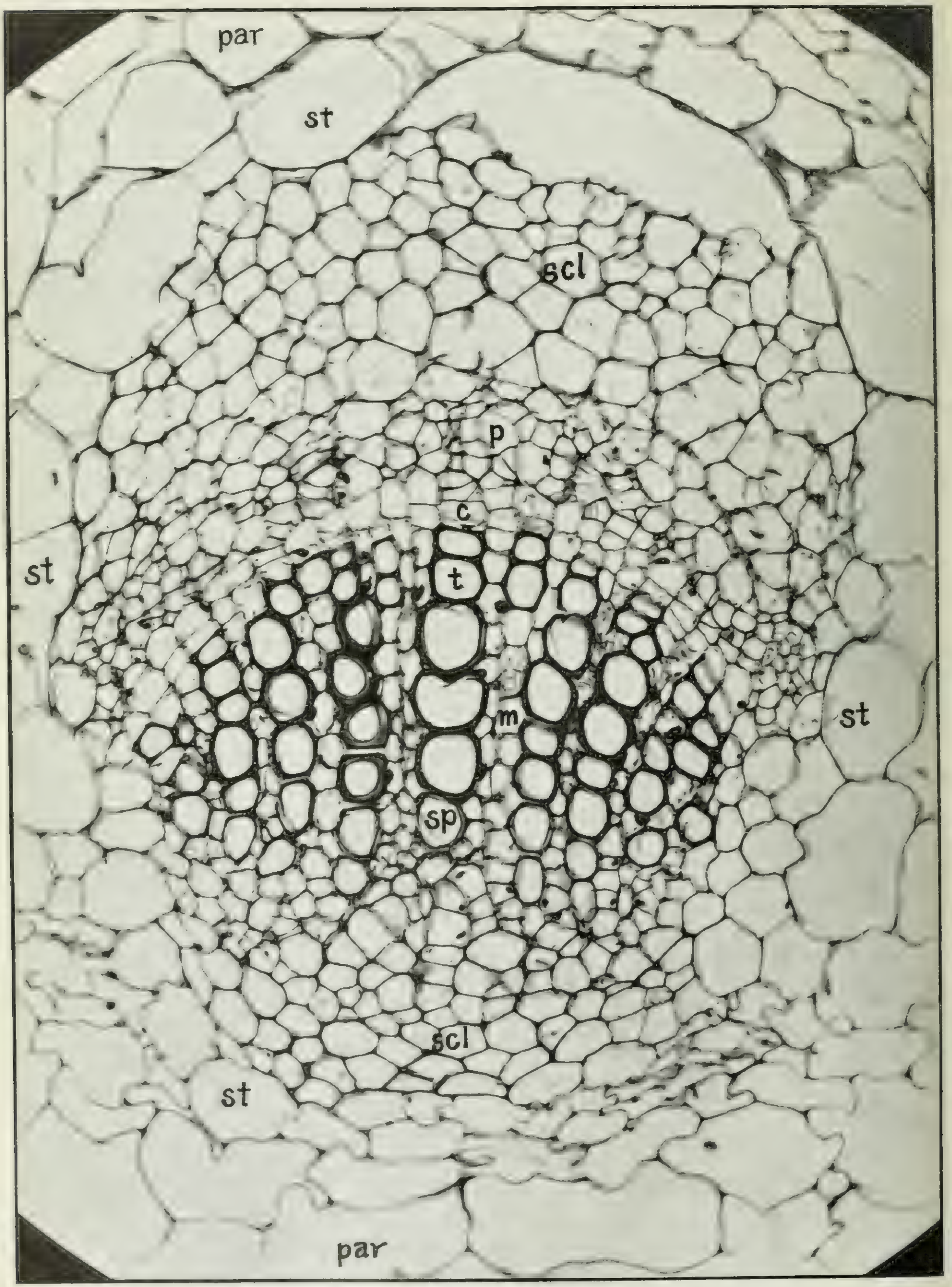
PLATES.



Daisy I. Cross section of a normal young branch in the outer region of which, i. e., between st and e, shallow needle pricks may produce tumors containing tracheids (p. 25).



Daisy I. Cross section of normal branch somewhat older than the preceding (p. 25).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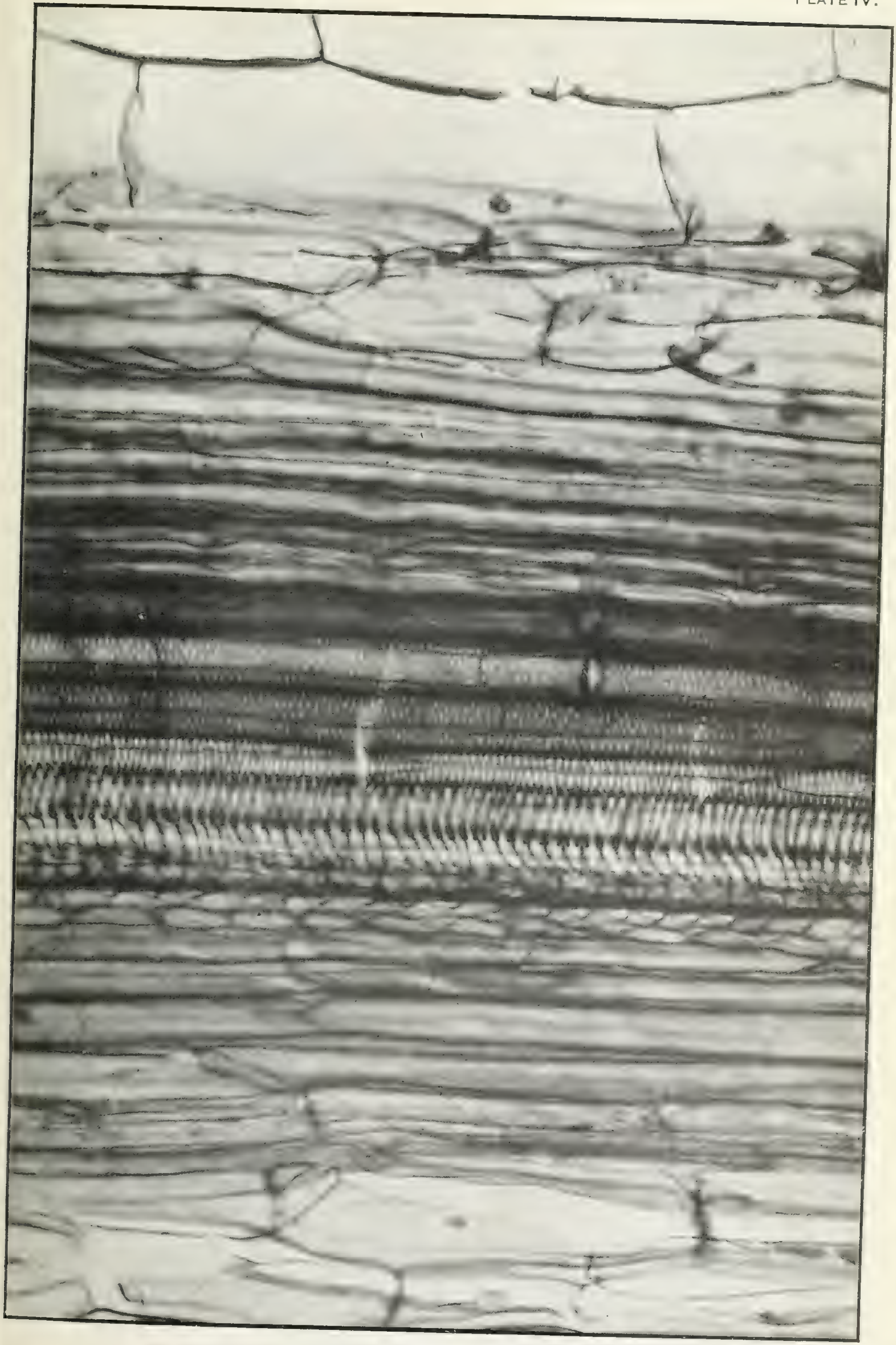
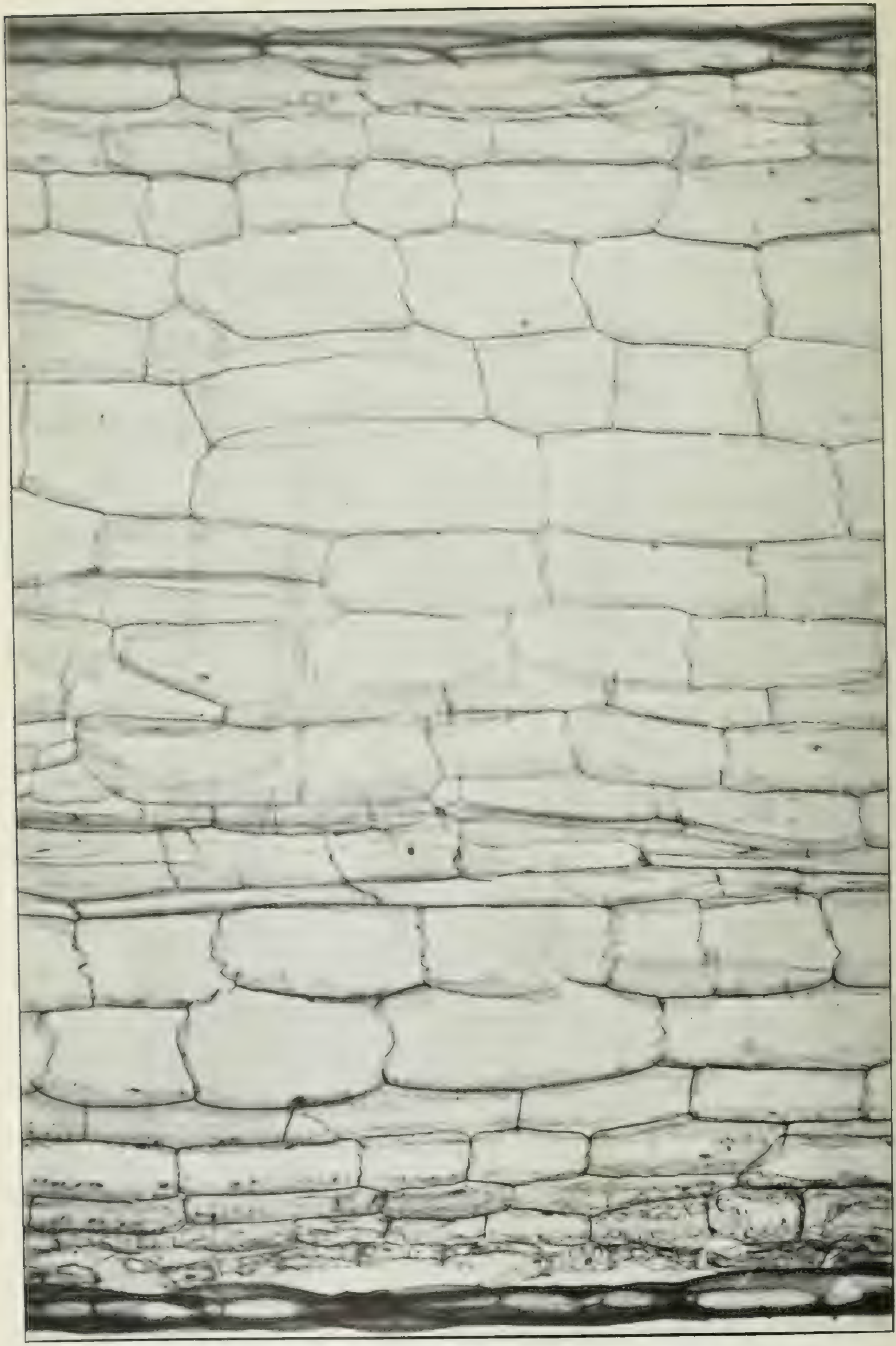
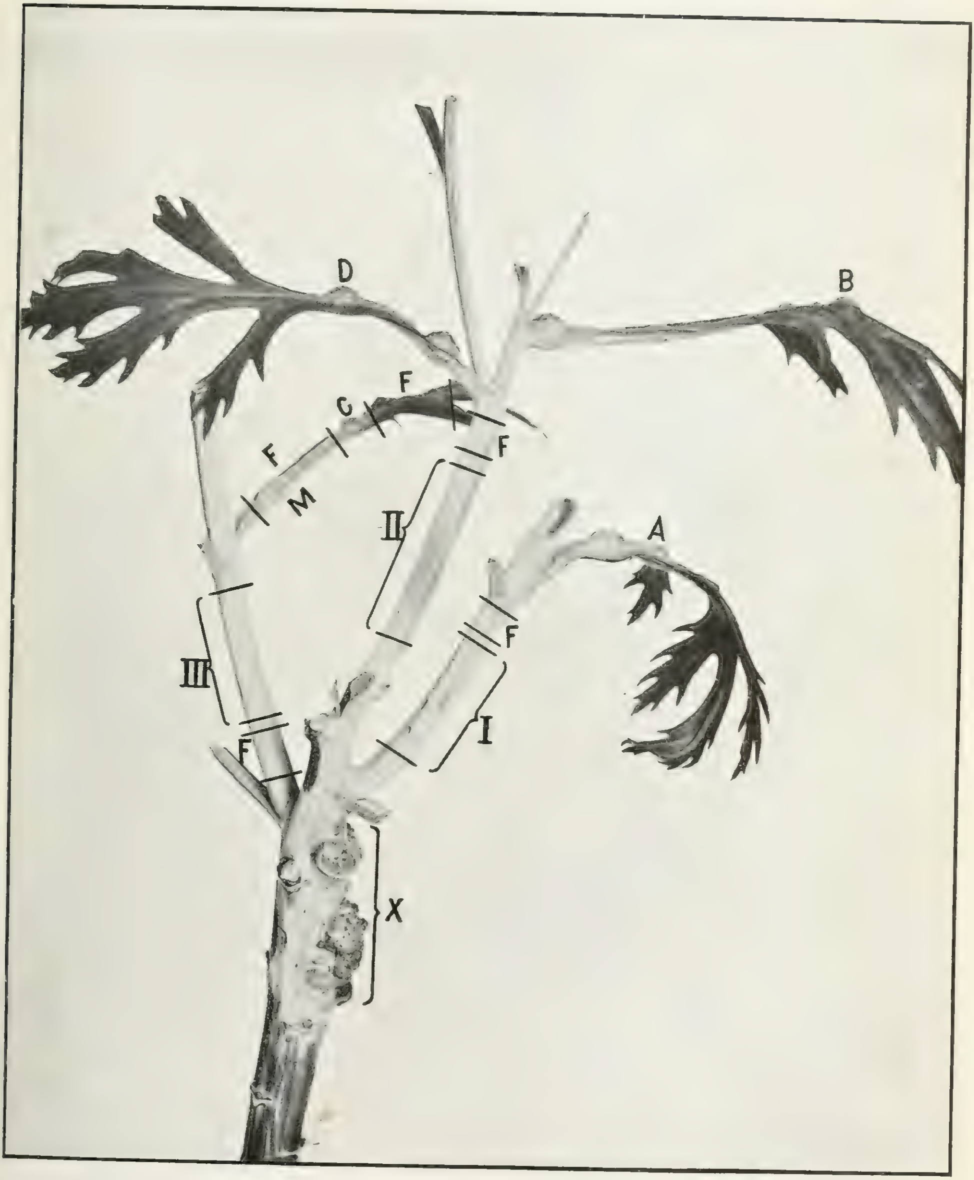
Daisy XIV. Cross section of a normal leaf-trace (p. 26), showing unilateral structure.



Daisy XXX. Longitudinal section of a normal leaf-trace (p. 26).



Daisy XXX. Longitudinal section of a normal petiole between leaf-traces (p. 26).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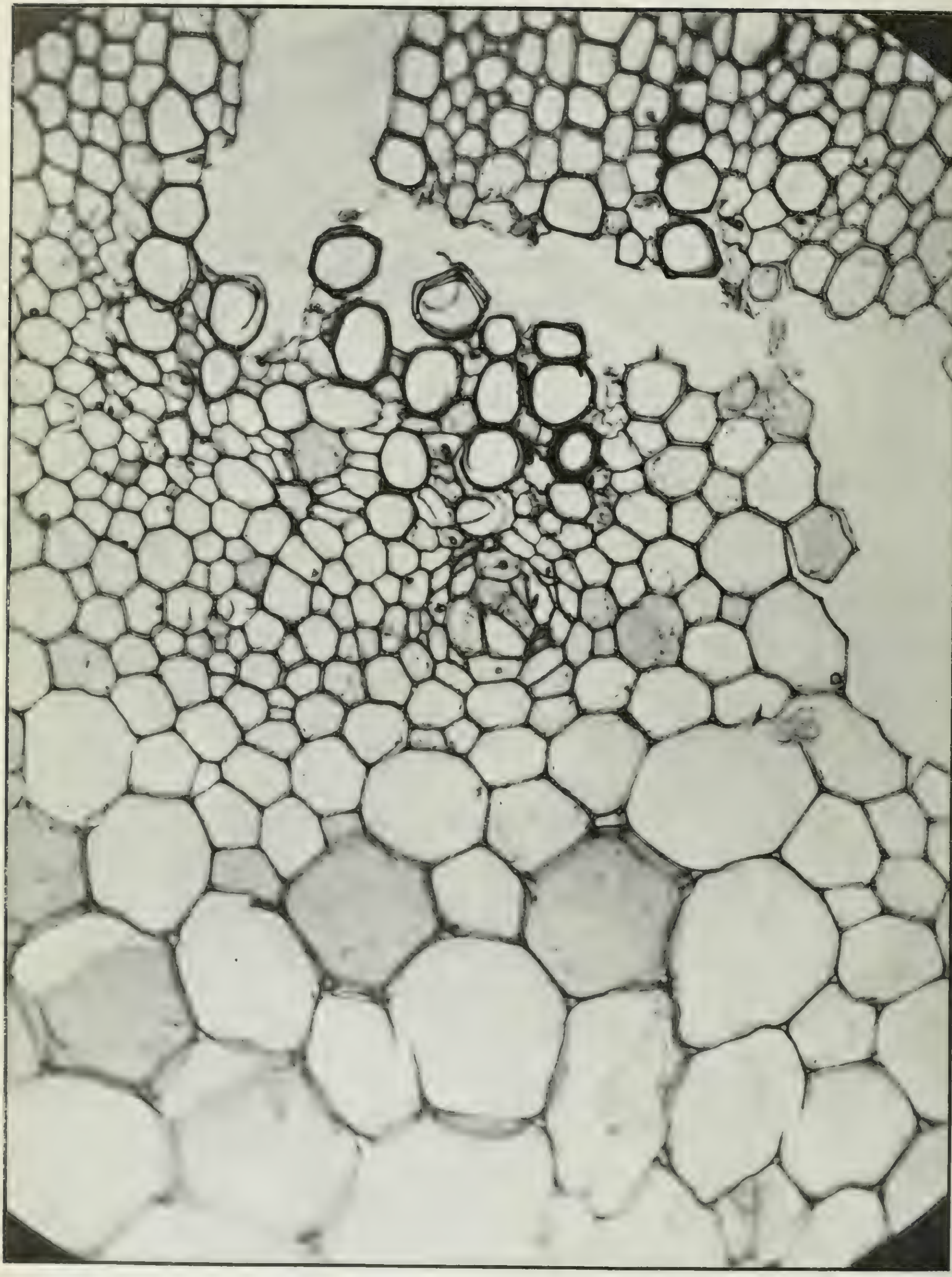
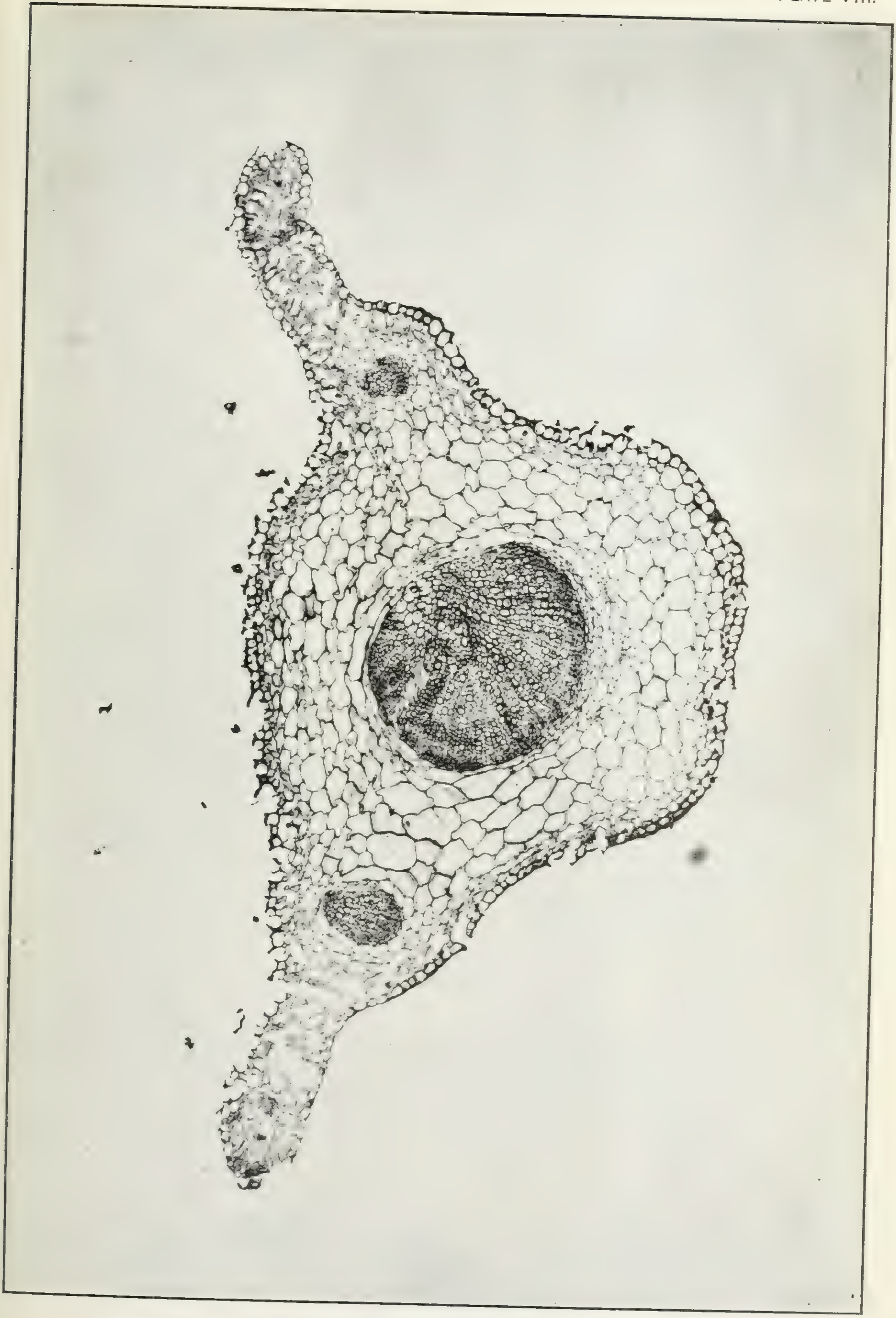
X

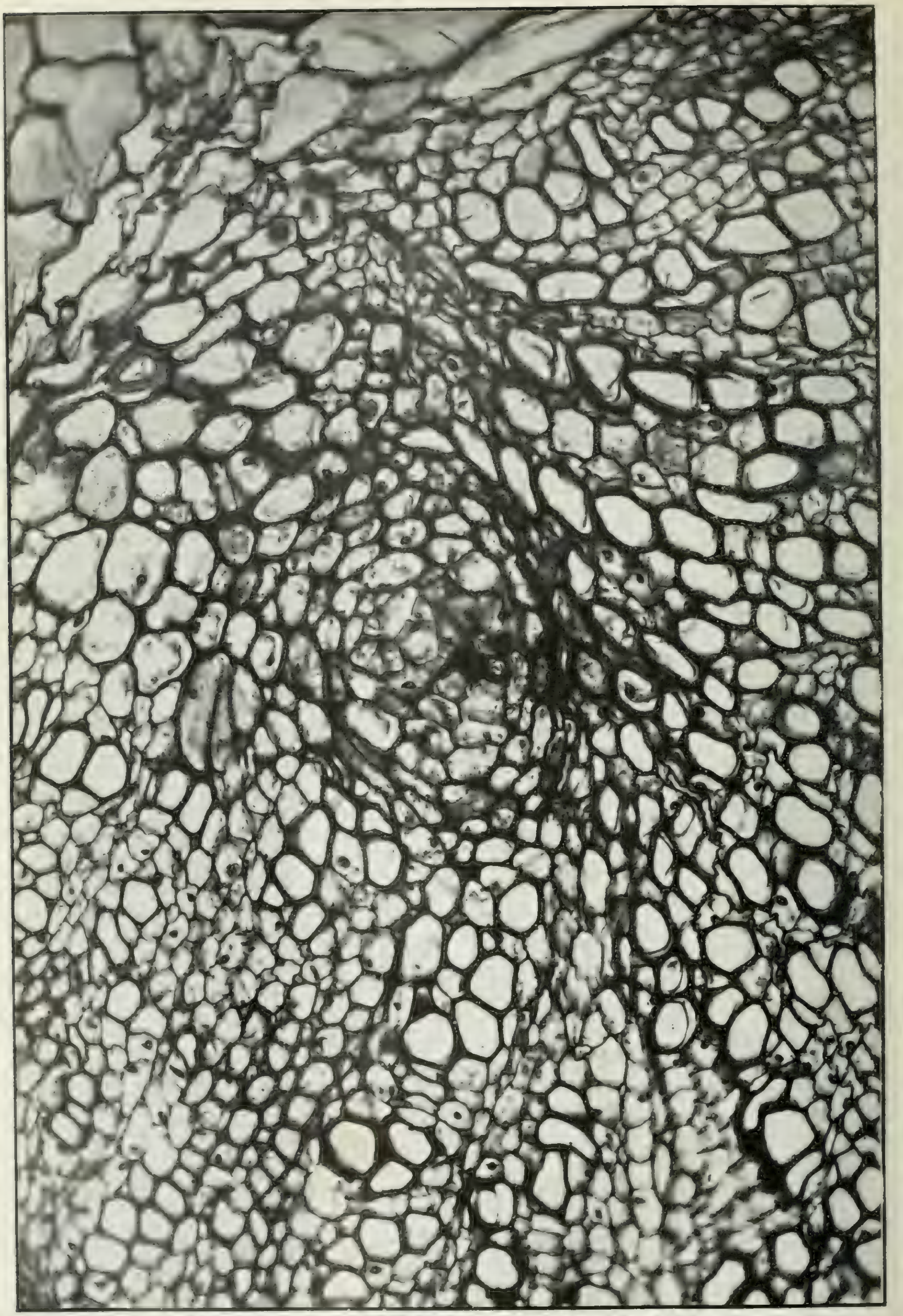
Daisy I. Part of plant showing primary stem tumors (at X) and secondary leaf tumors (p. 26).



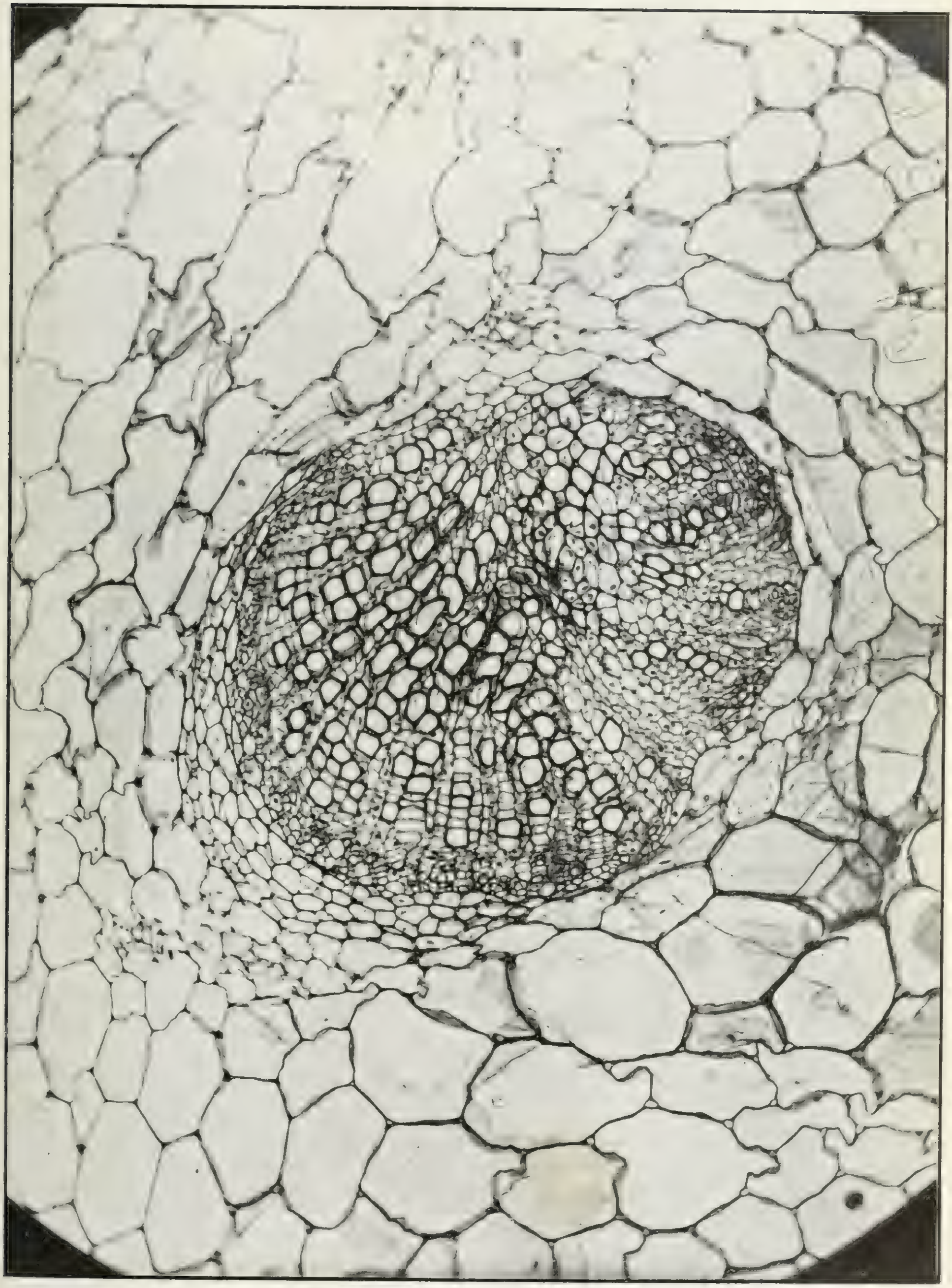
Daisy 1. Cross-section of Branch III between tumors, showing tumor-strand which passes into petiole C (p. 27).



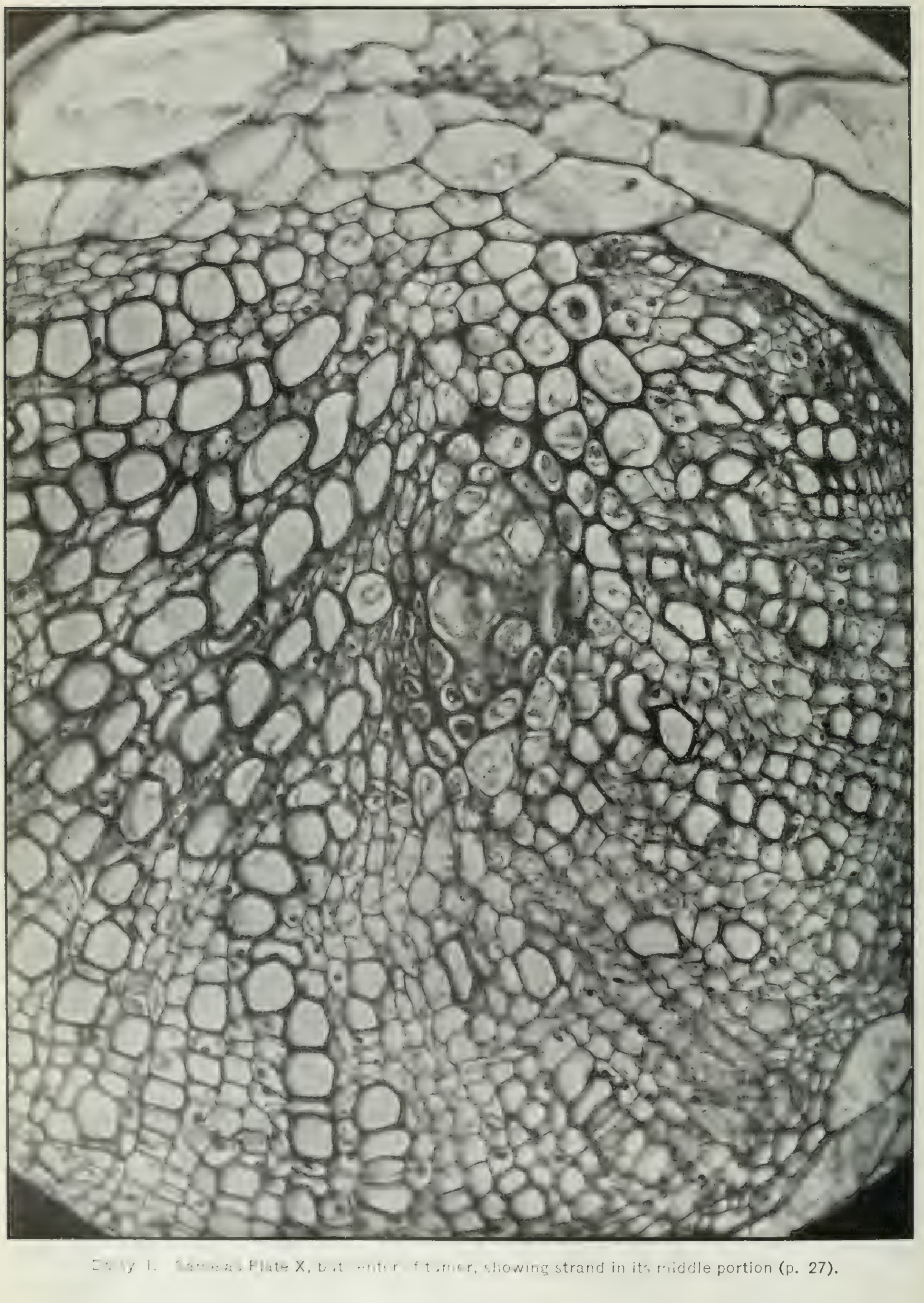
Daisy I. Cross section of petiole C, central leaf trace diseased (p. 27).



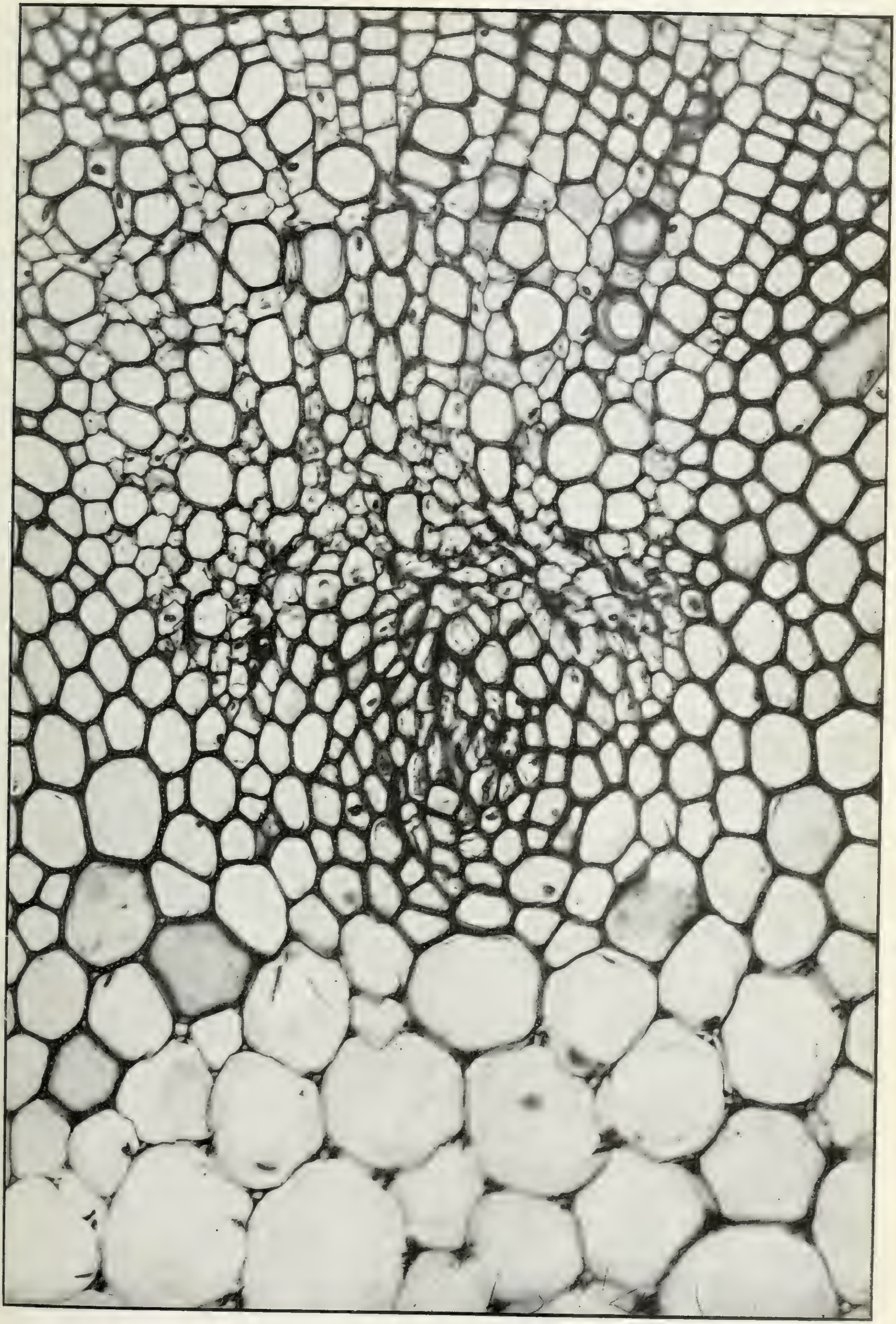
Daisy I. Center of tumor in petiole C, showing the tumor-strand (p. 27).



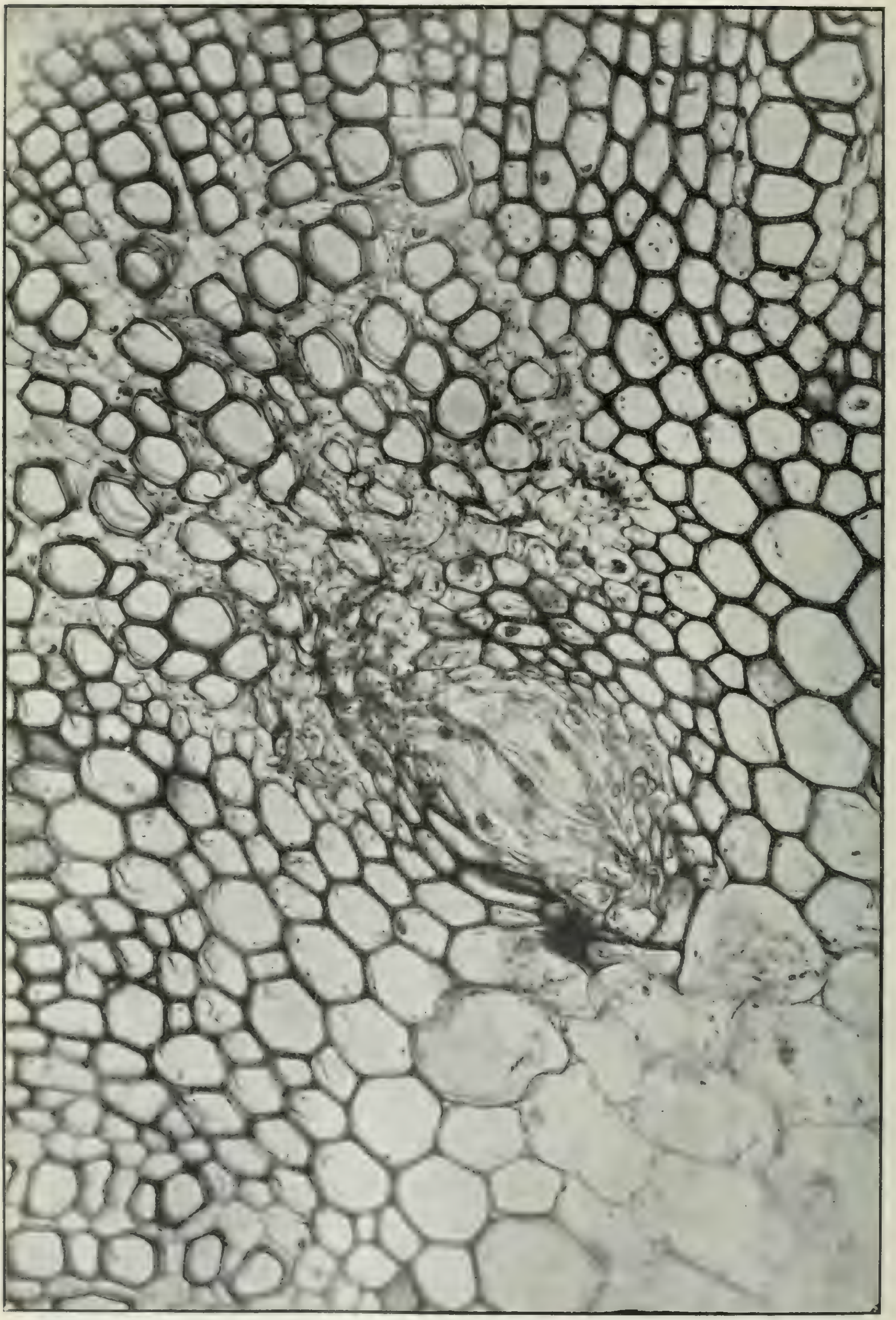
Daisy I. Cross section of petiole C at another level, showing conversion of leaf-trace into a secondary tumor (p. 27).



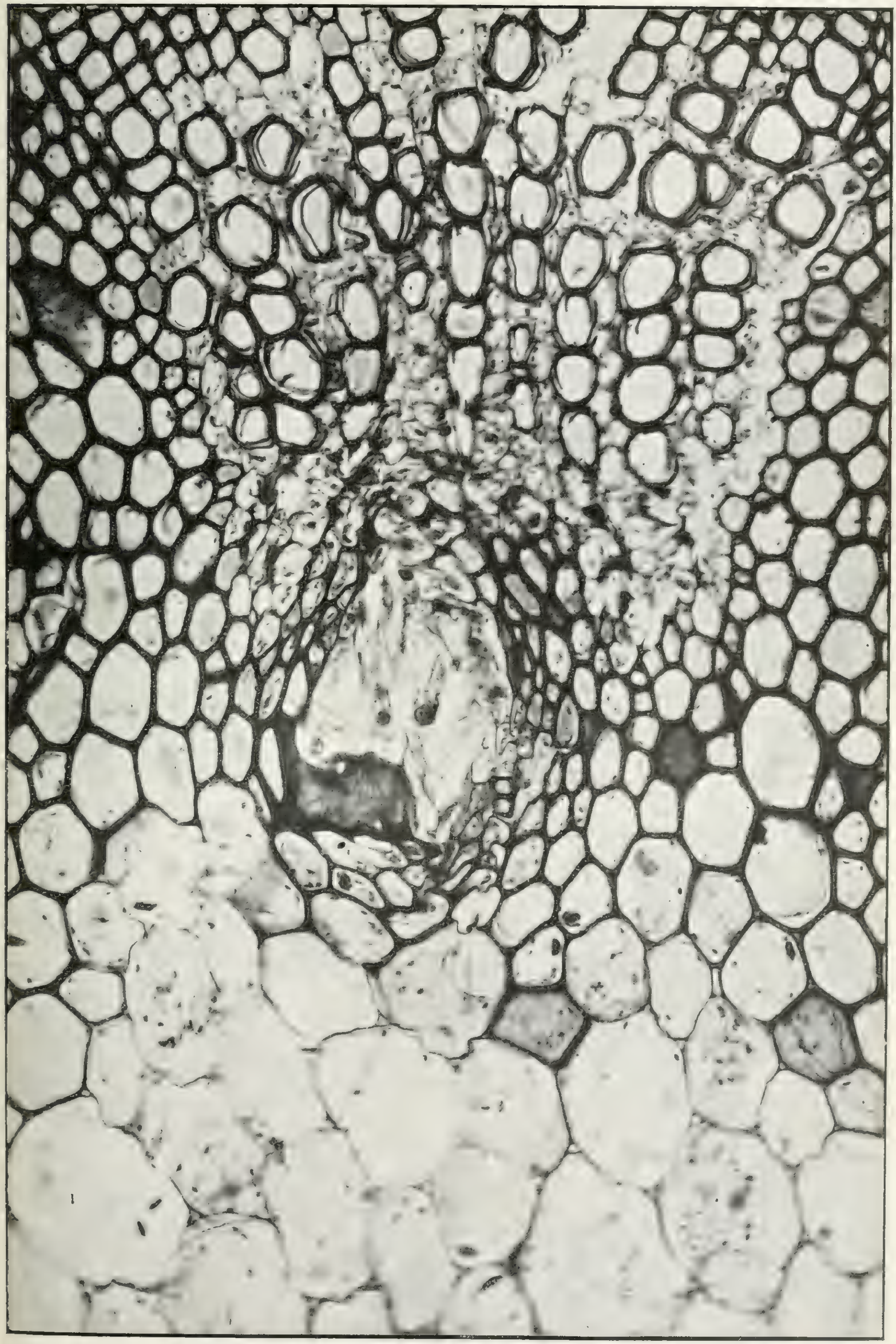
Daisy I. Same as Plate X, but center of tumor, showing strand in its middle portion (p. 27).



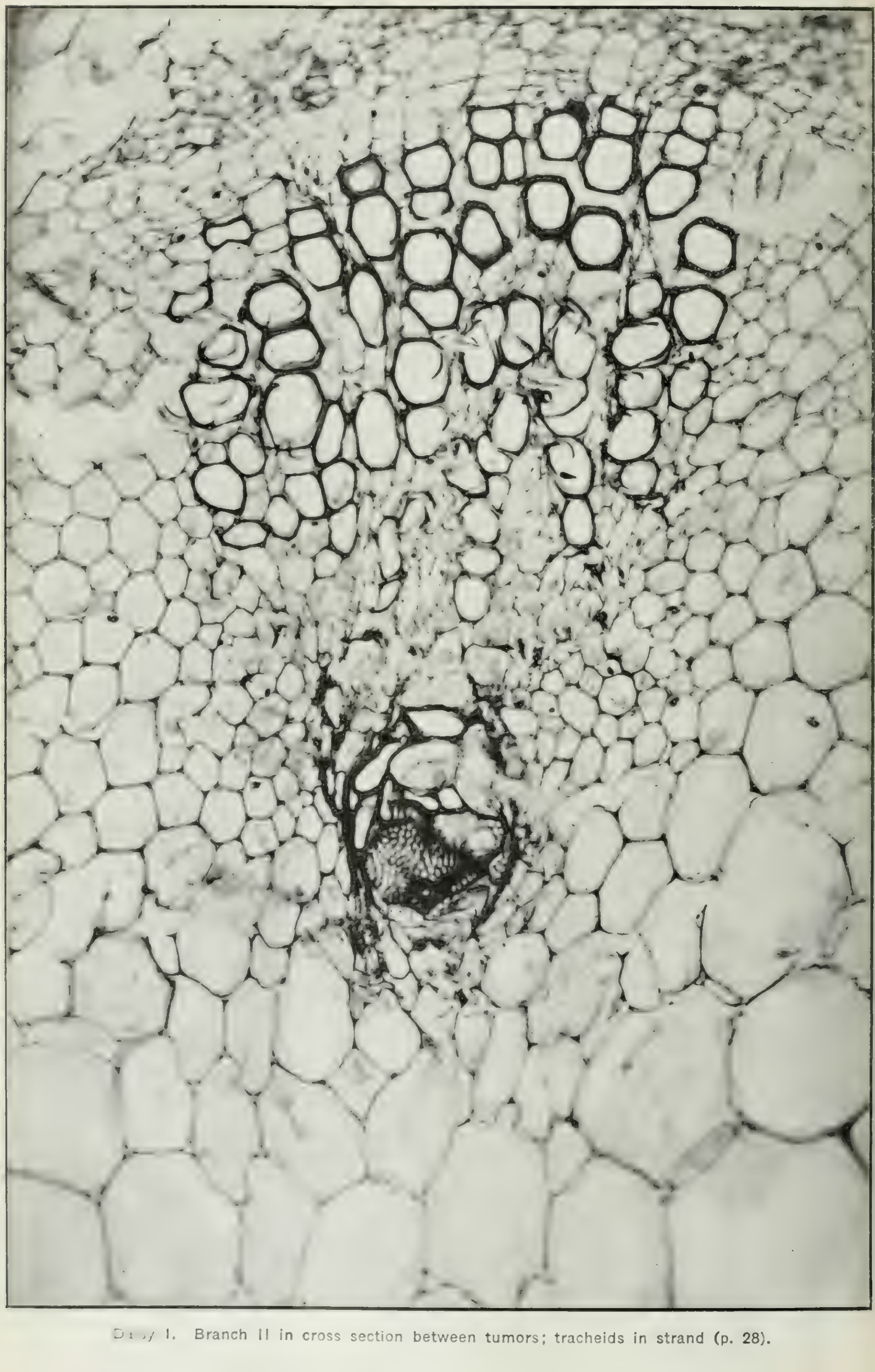
Daisy I. Branch I in cross section between tumors, showing small-celled tumor-strand (p. 28).



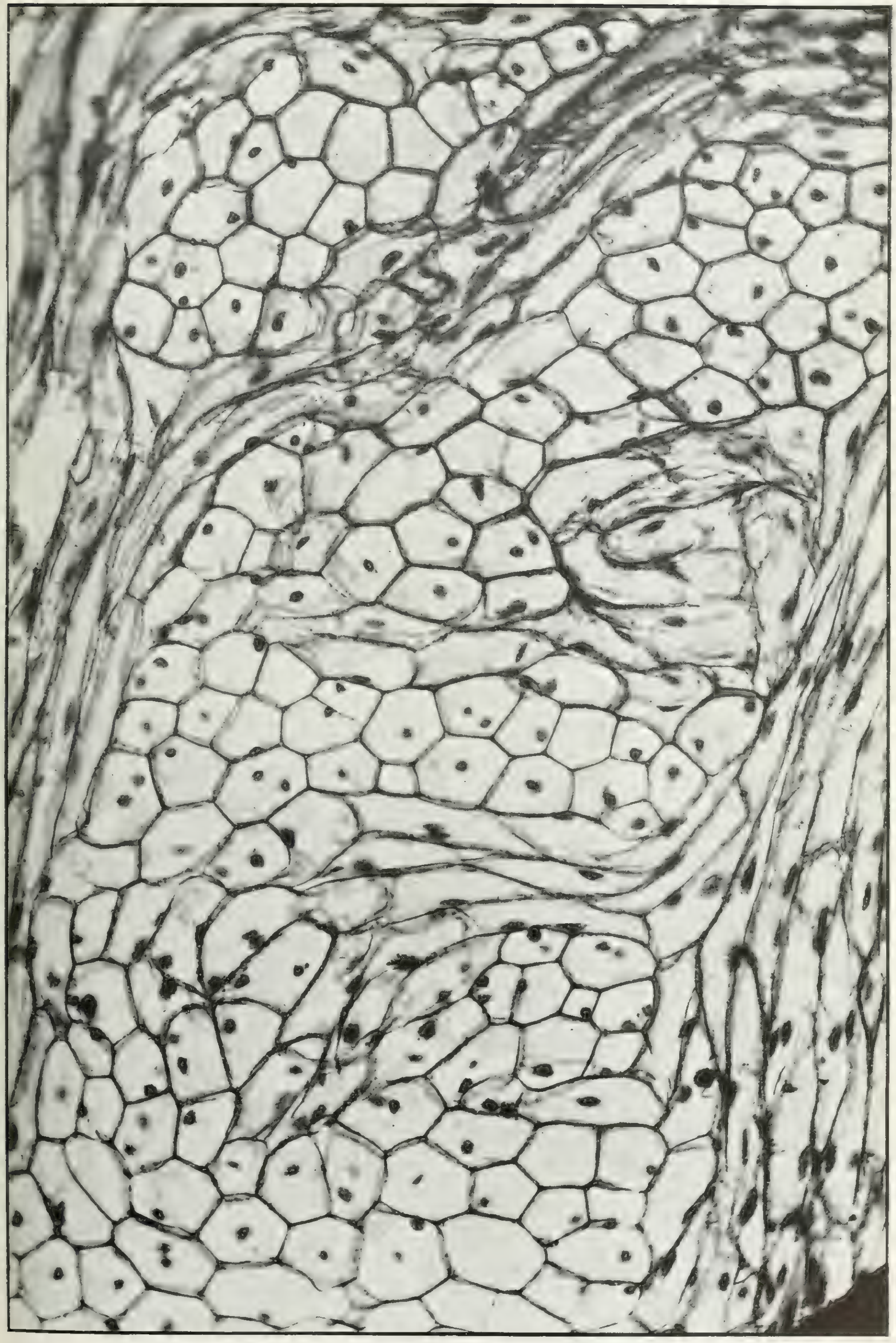
Daisy, I. Branch I in cross section at another level, showing large, soft cells in the tumor-strand (p. 28).



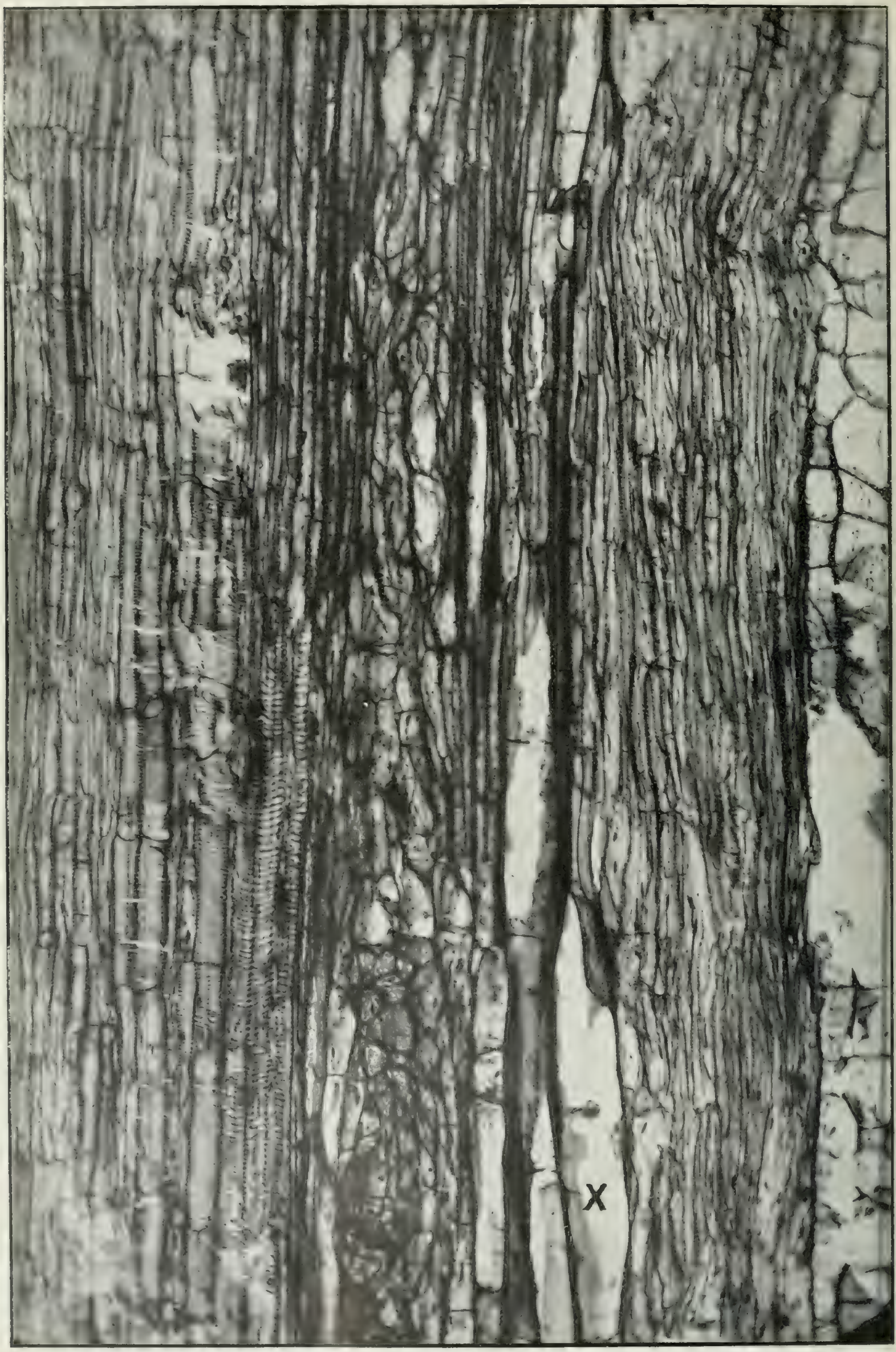
Daisy I. Cross section of Branch I, showing tracheids developing in the tumor-strand (× 28).



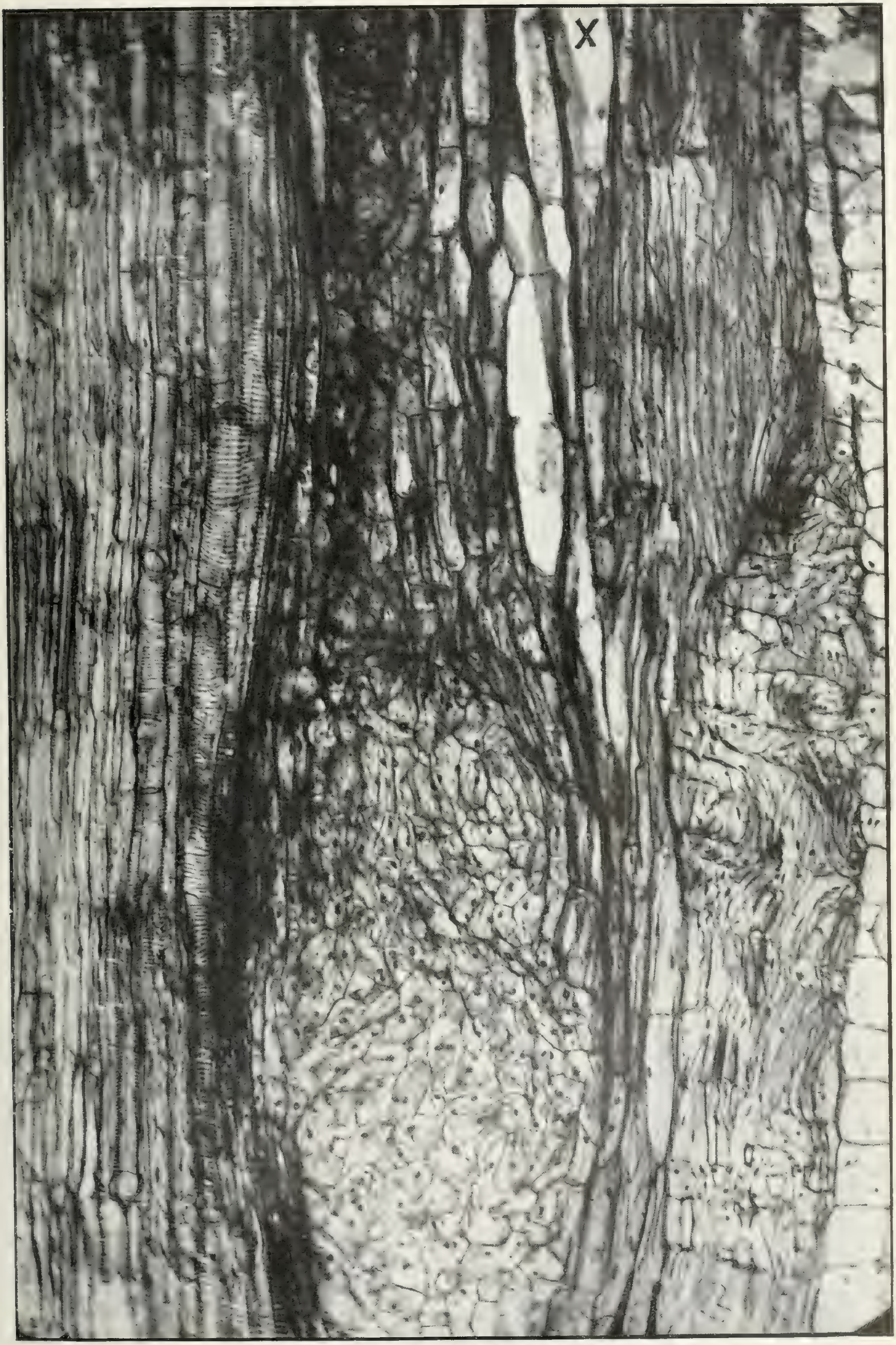
Daisy I. Branch II in cross section between tumors; tracheids in strand (p. 28).



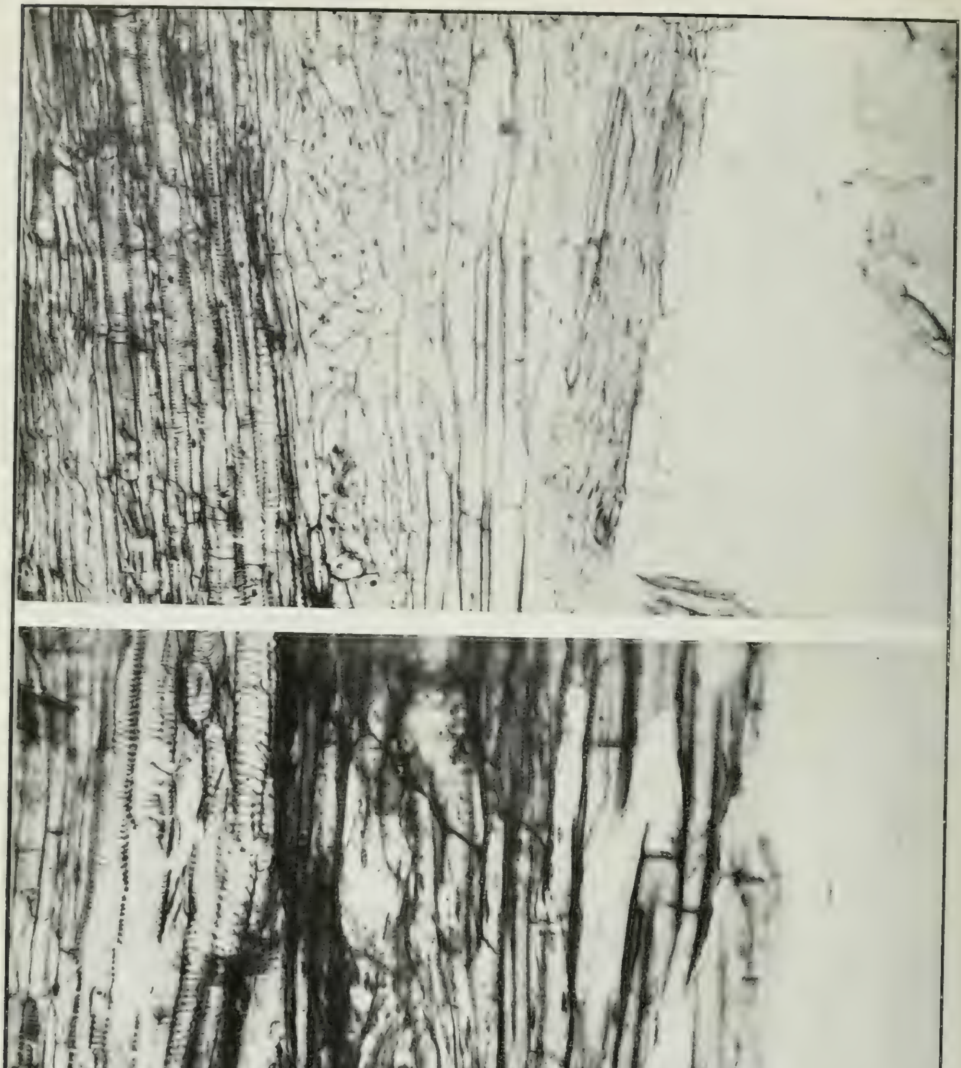
Daisy I. Petiole C. Tumor tissue with bi-nucleate cells (p. 28).



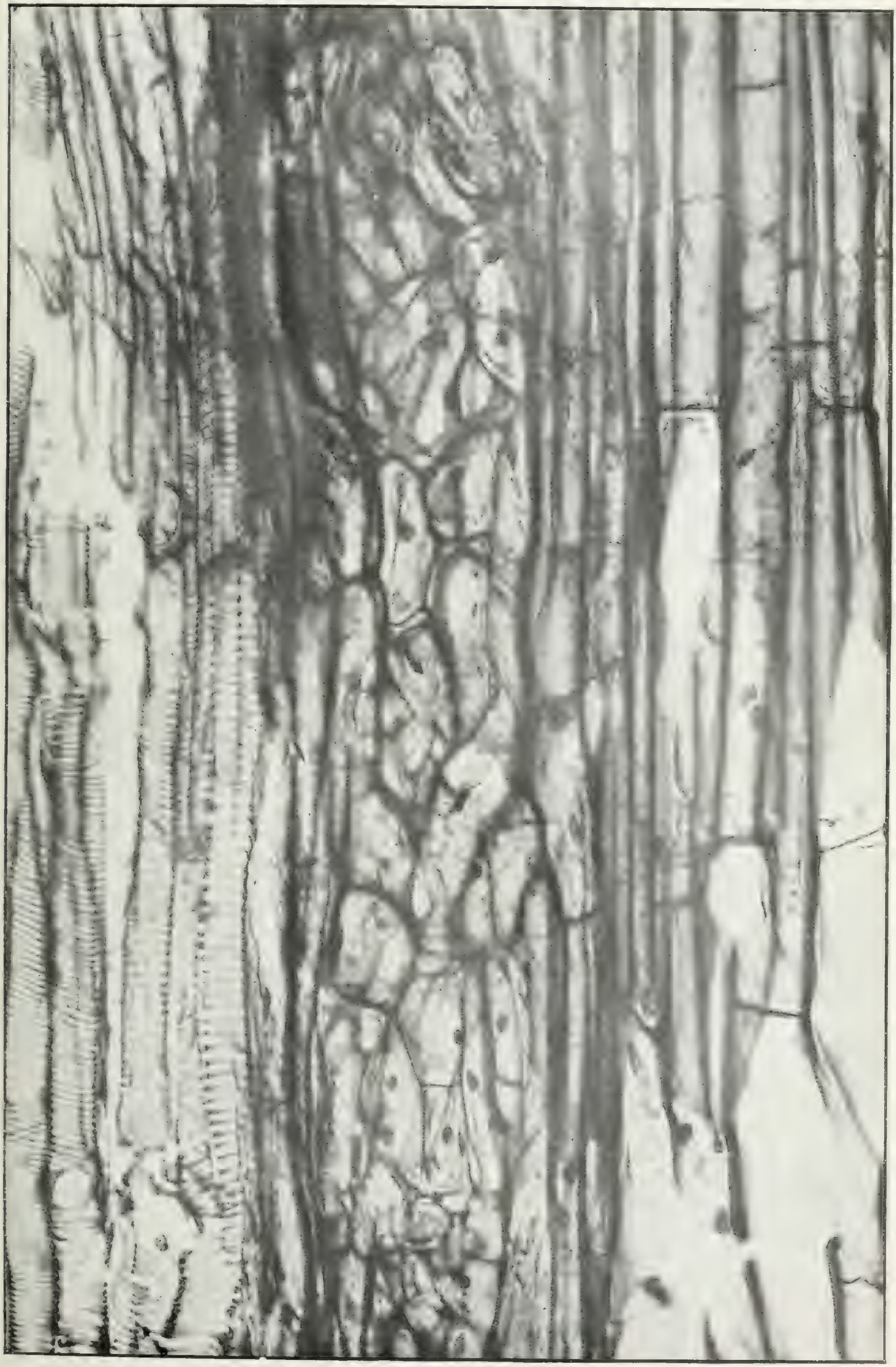
Daisy I. Longitudinal section of petiole C, showing tumor-strand (p. 28).



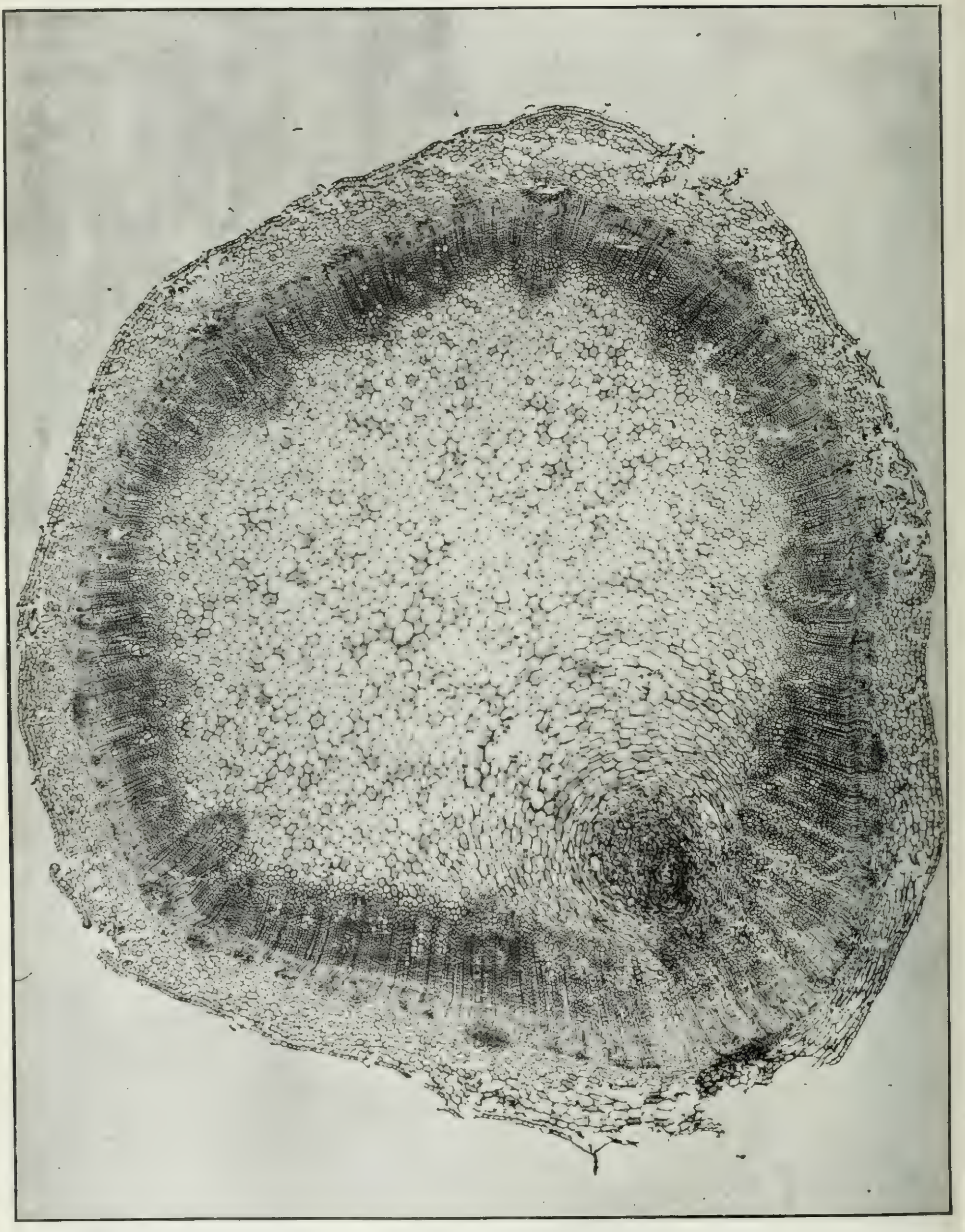
Daisy I. Continuation of Plate XVII, strand enlarging into a tumor (p. 28).



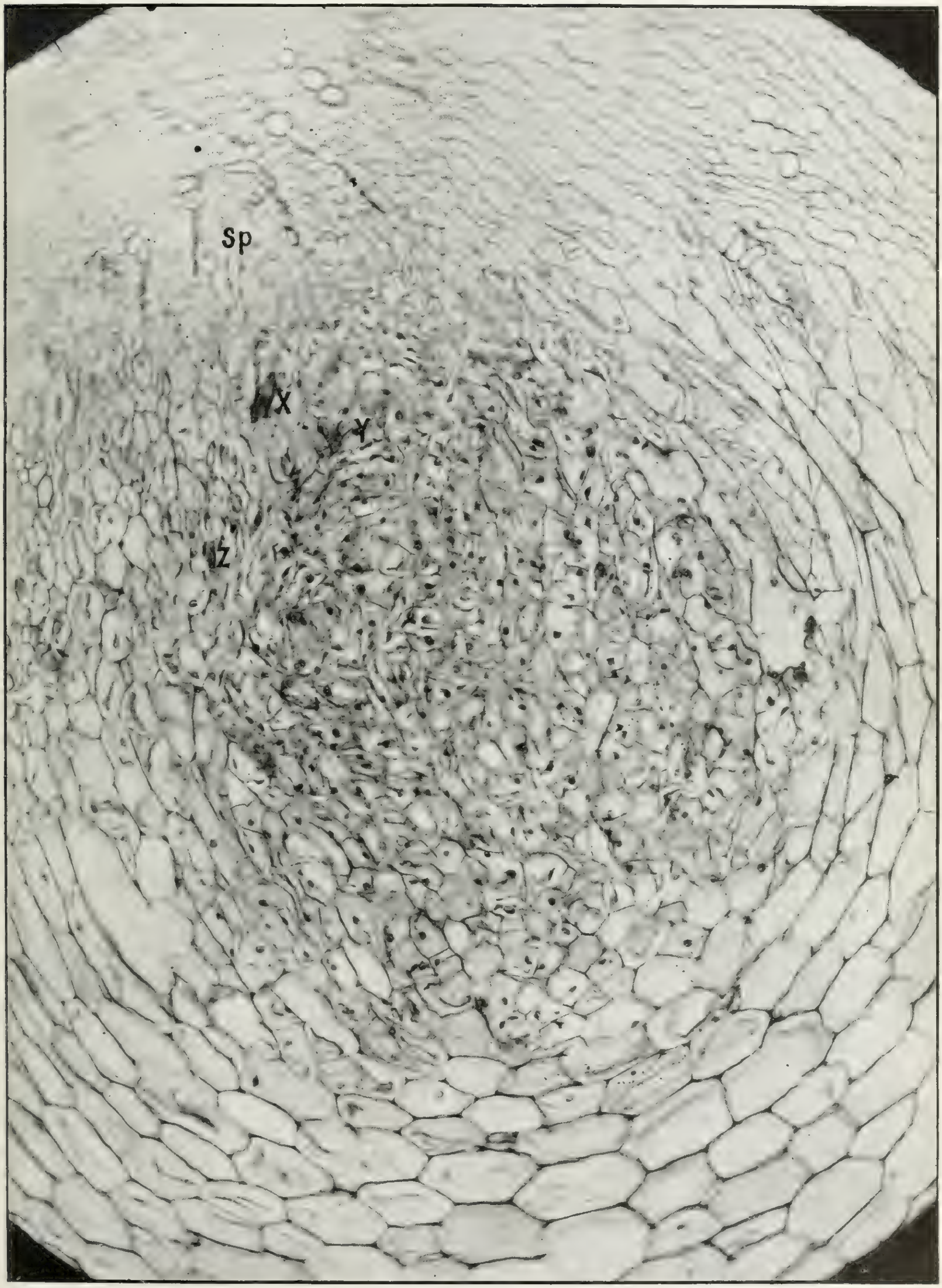
Daisy I. Continuation of Plate XVIII, showing tumor-strand (p. 28).



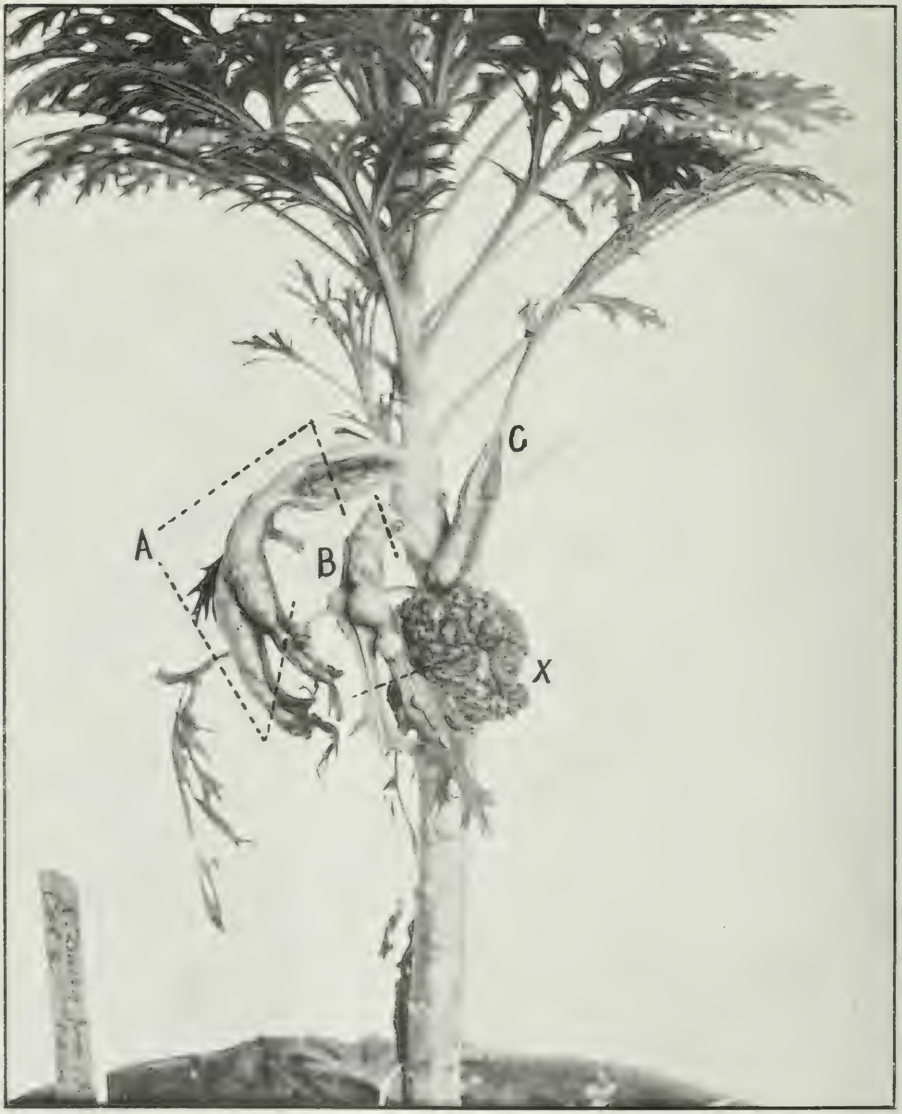
Daisy I. Continuation of Plate XIX, but tumor-strand further magnified (p. 29).



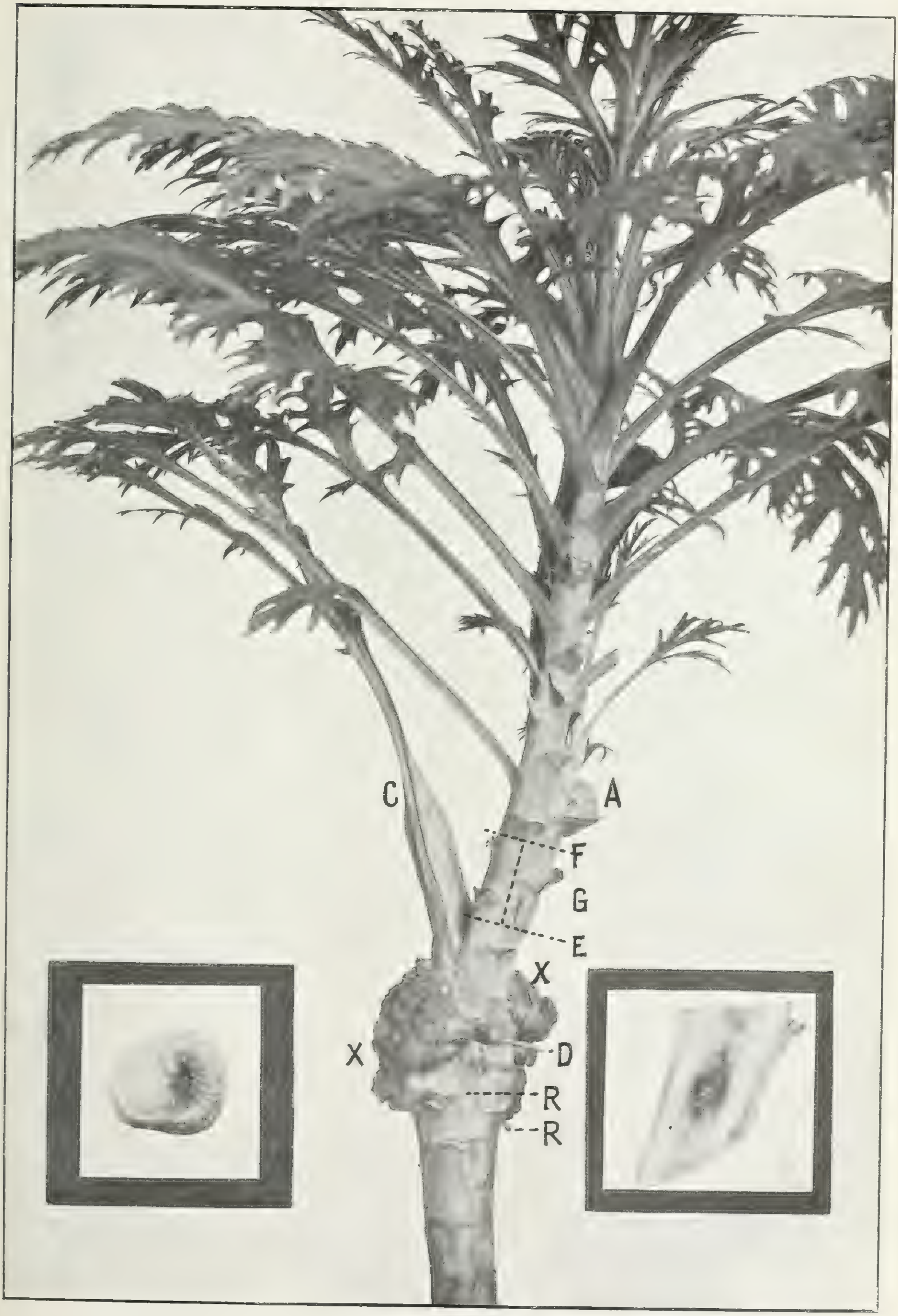
Daisy II. Cross section of stem between tumors, showing tumor-strand. The wood on that side is slightly enlarged and the pith is compressed. The rest of the stem is normal (p. 29).



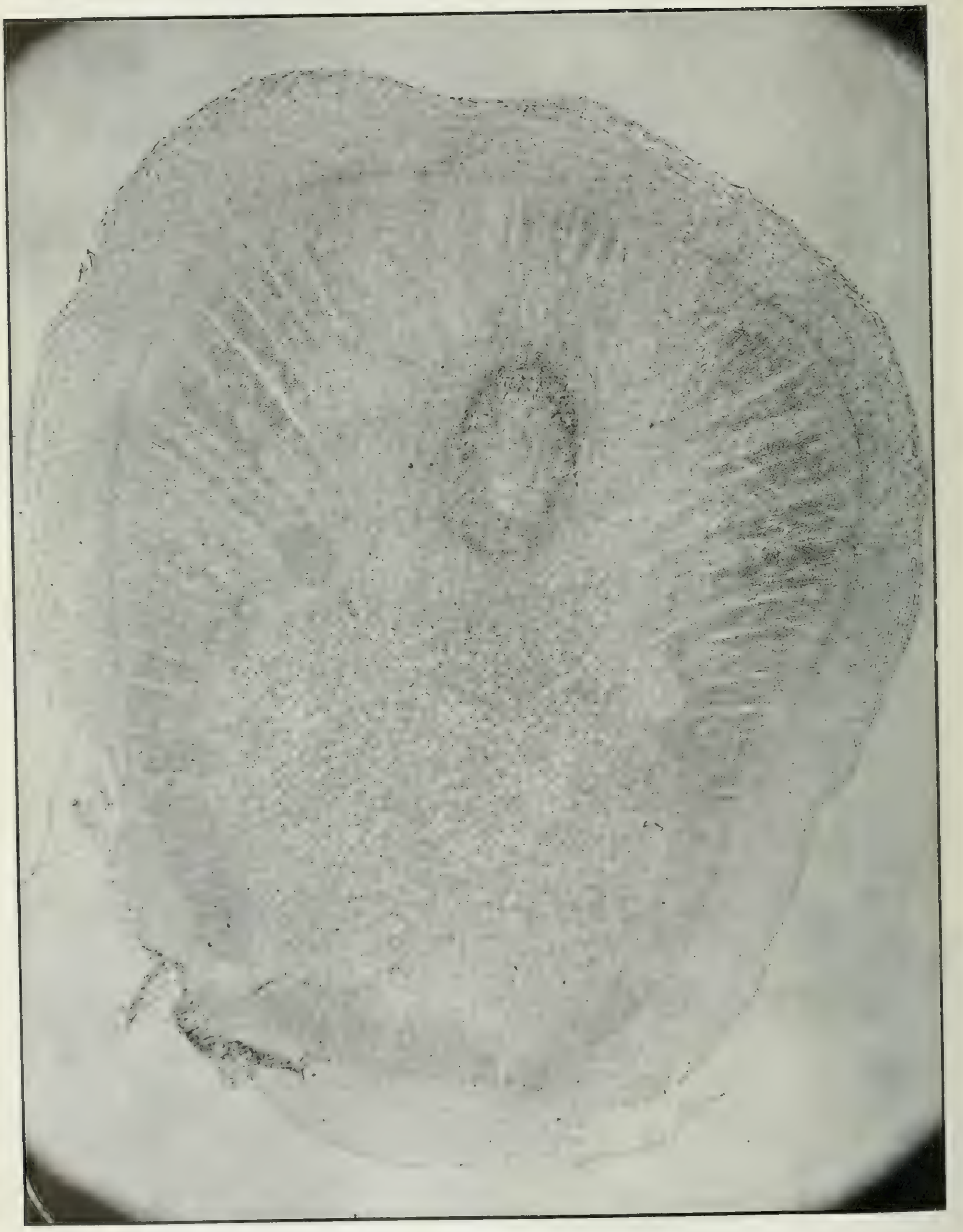
Daisy II. Same as Plate XXI, but tumor-strand further magnified; at the top crushed and displaced spirals (p. 29).



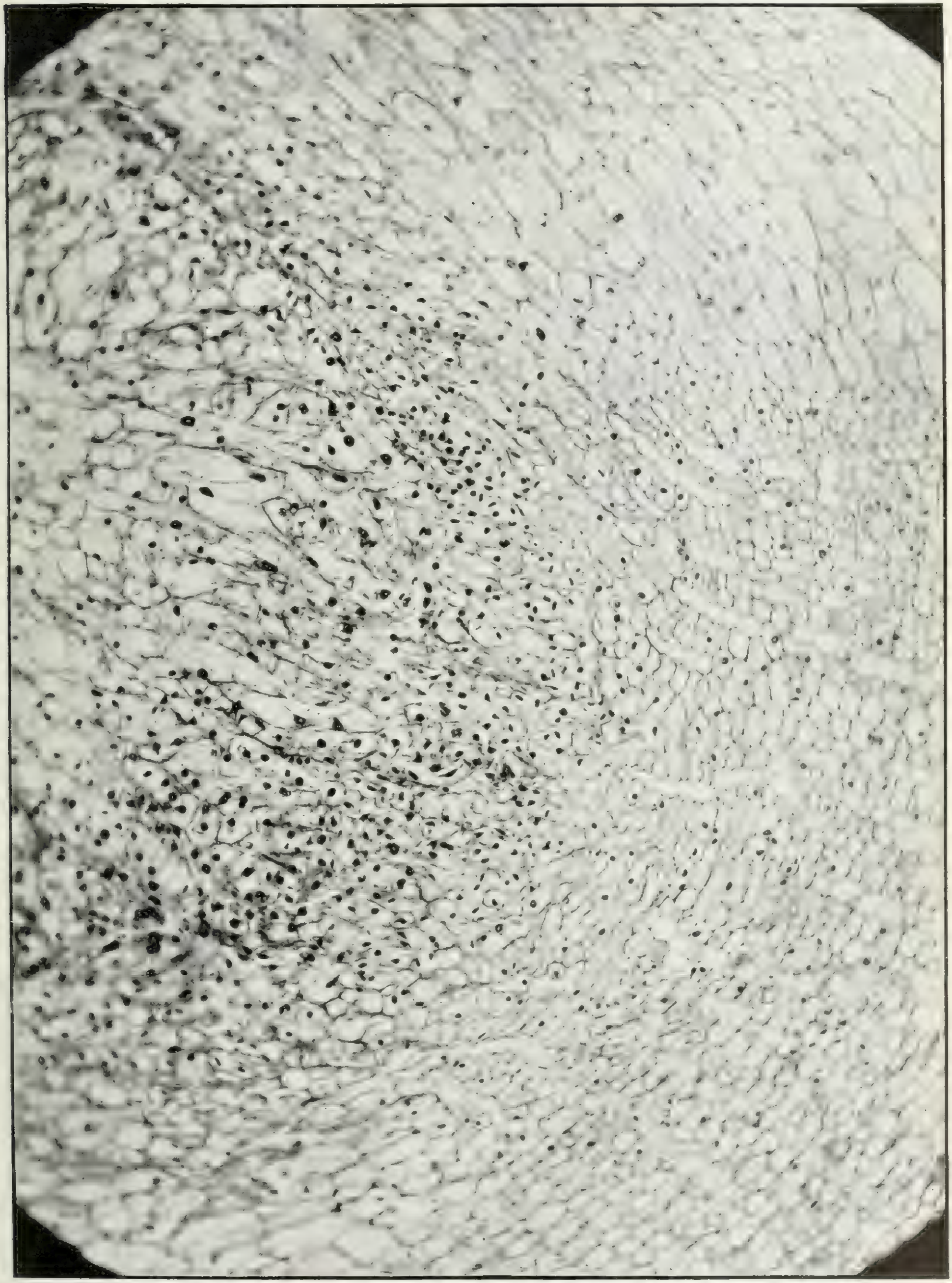
Daisy 7. Inoculated plant, showing a primary stem tumor and leaves converted into secondary tumors (p. 29).



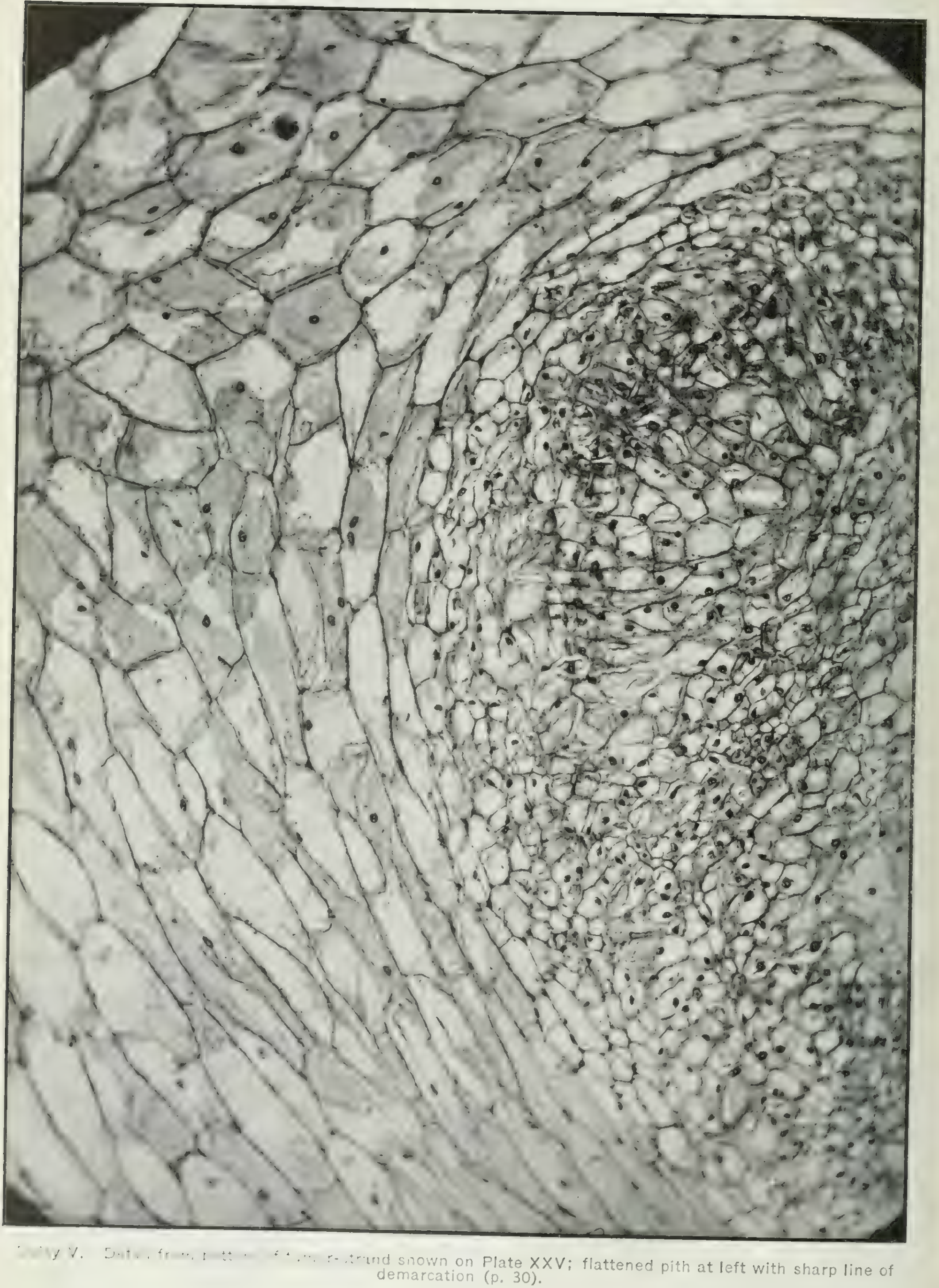
Daisy V. Other side of the plant, with sections of the abnormal stem (p. 30).



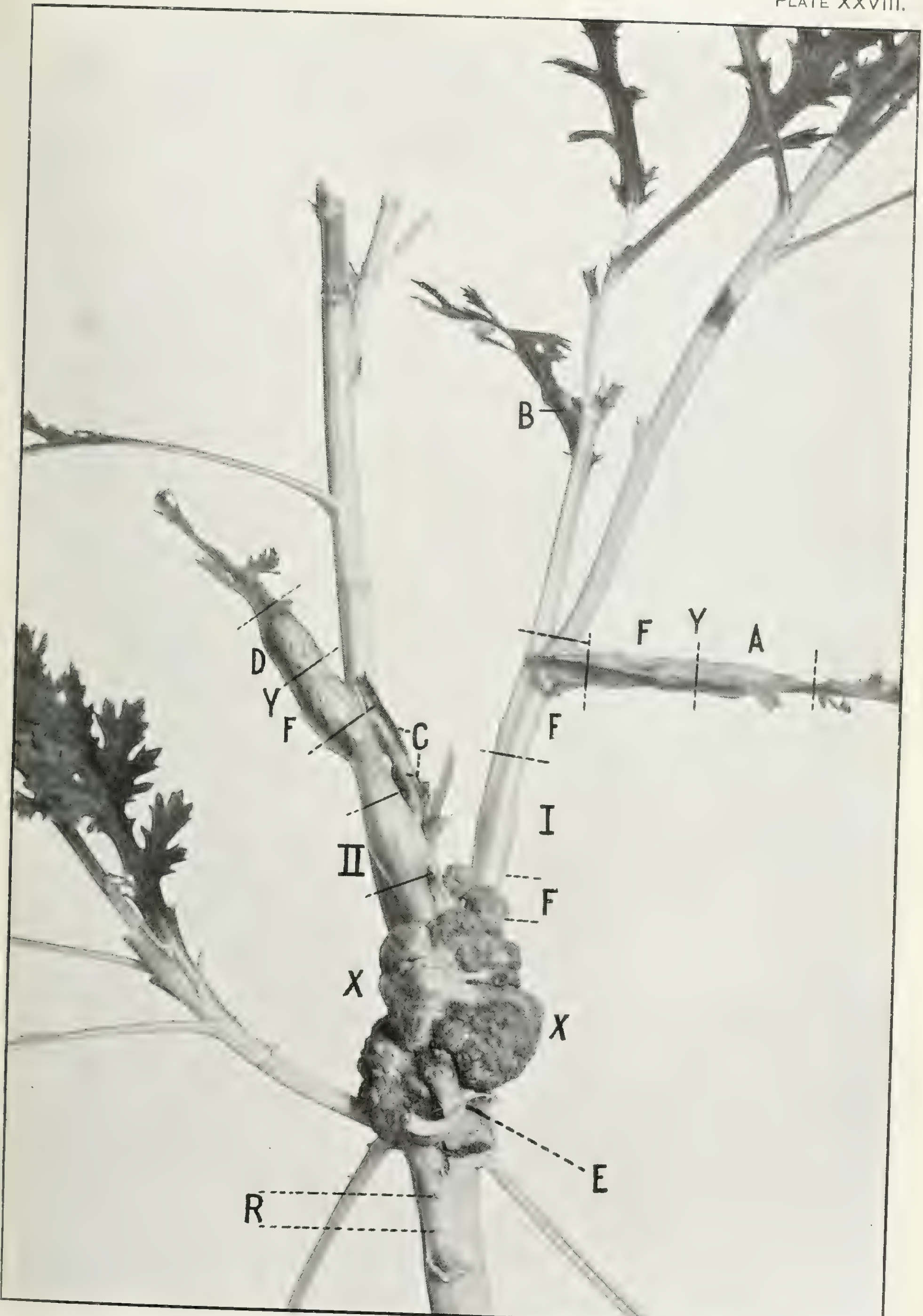
Daisy V. Enlarged cross section of stem between tumors, showing a large tumor-strand with marked enlargement of the wood on that side (p. 30).



Daisy V. Detail from top of tumor-strand on Plate XXV, showing gradual transition into the wood (p. 30).



Daisy V. Detail from bottom of tumor-strand shown on Plate XXV; flattened pith at left with sharp line of demarcation (p. 30).


B
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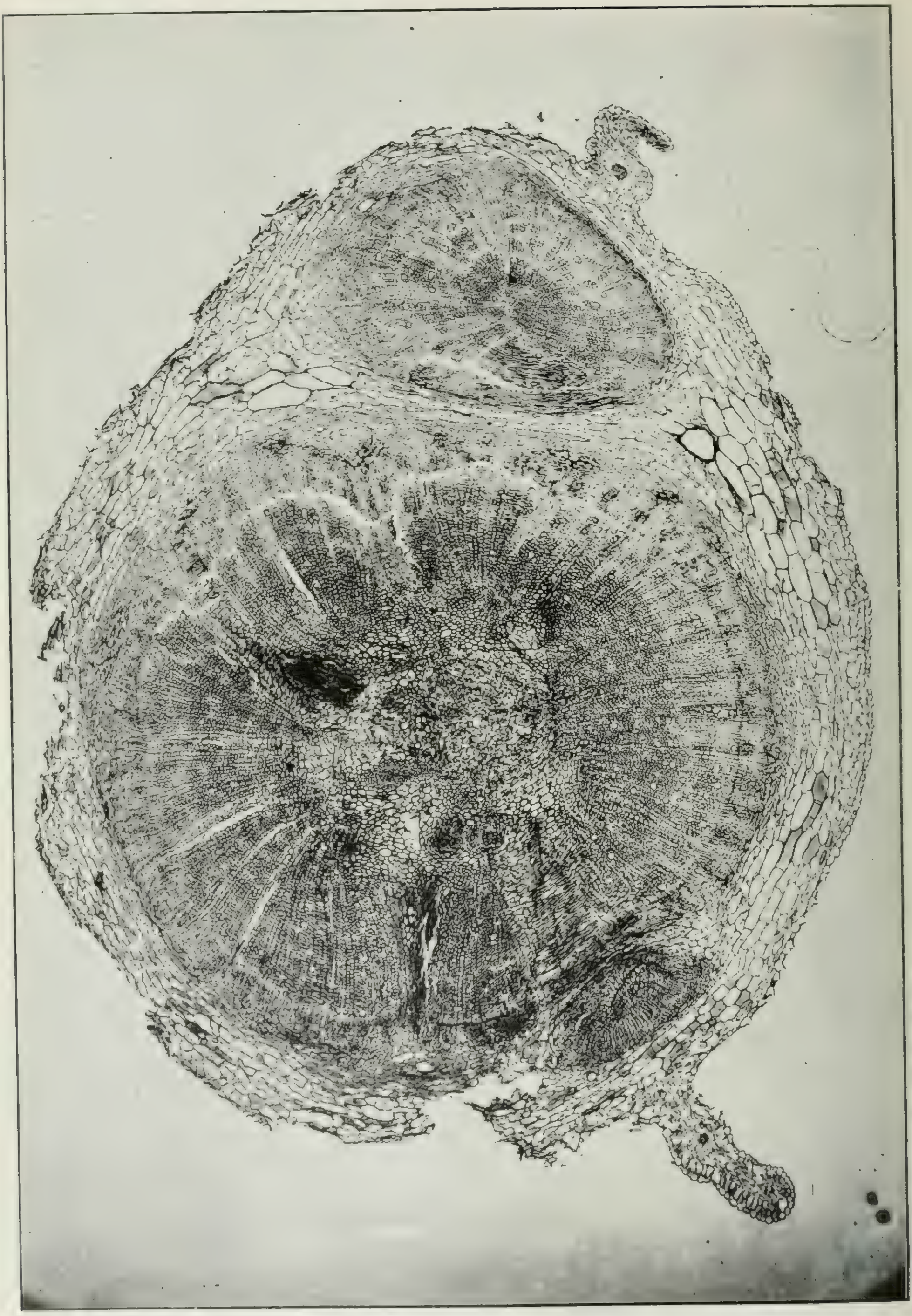
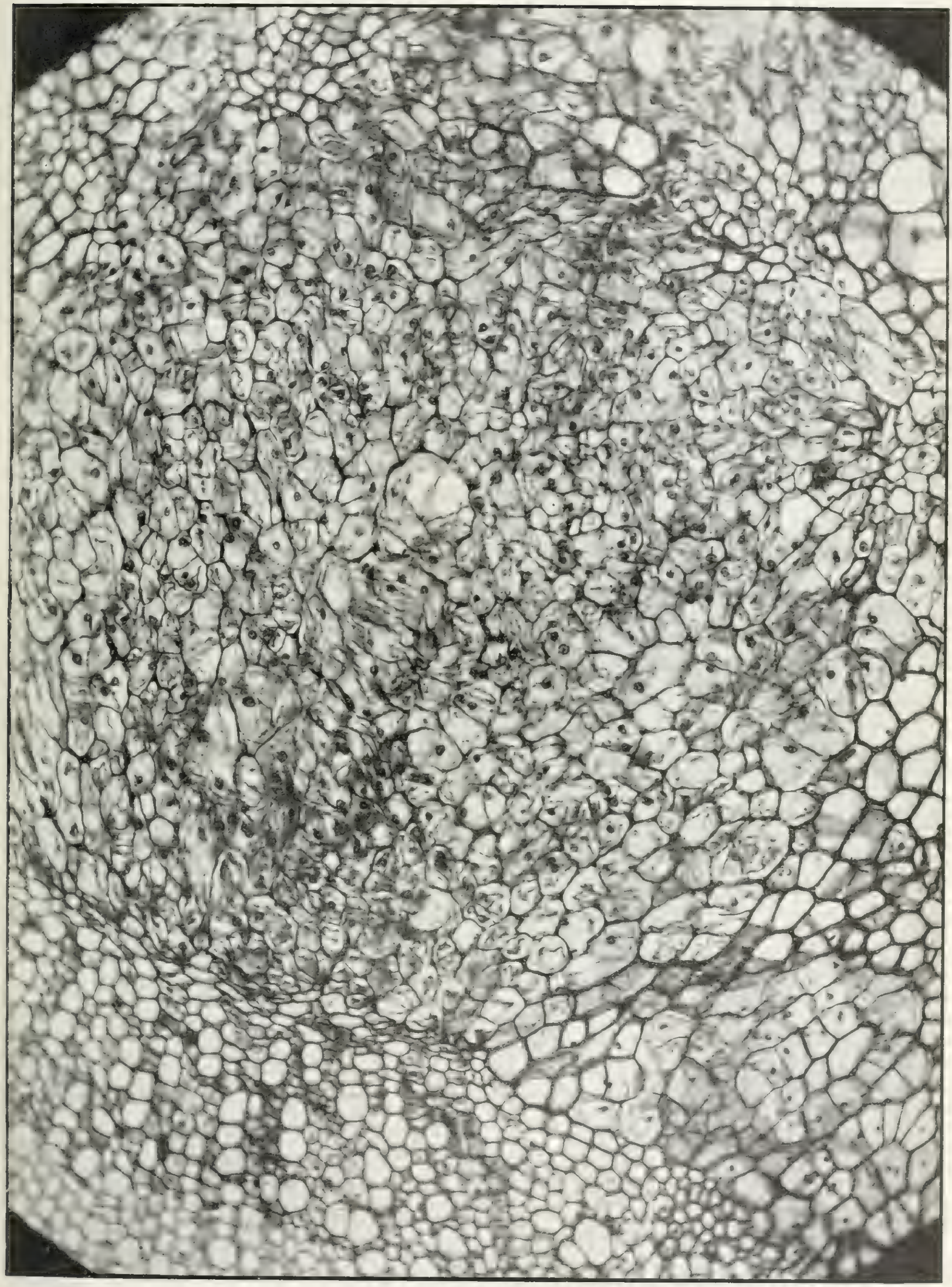
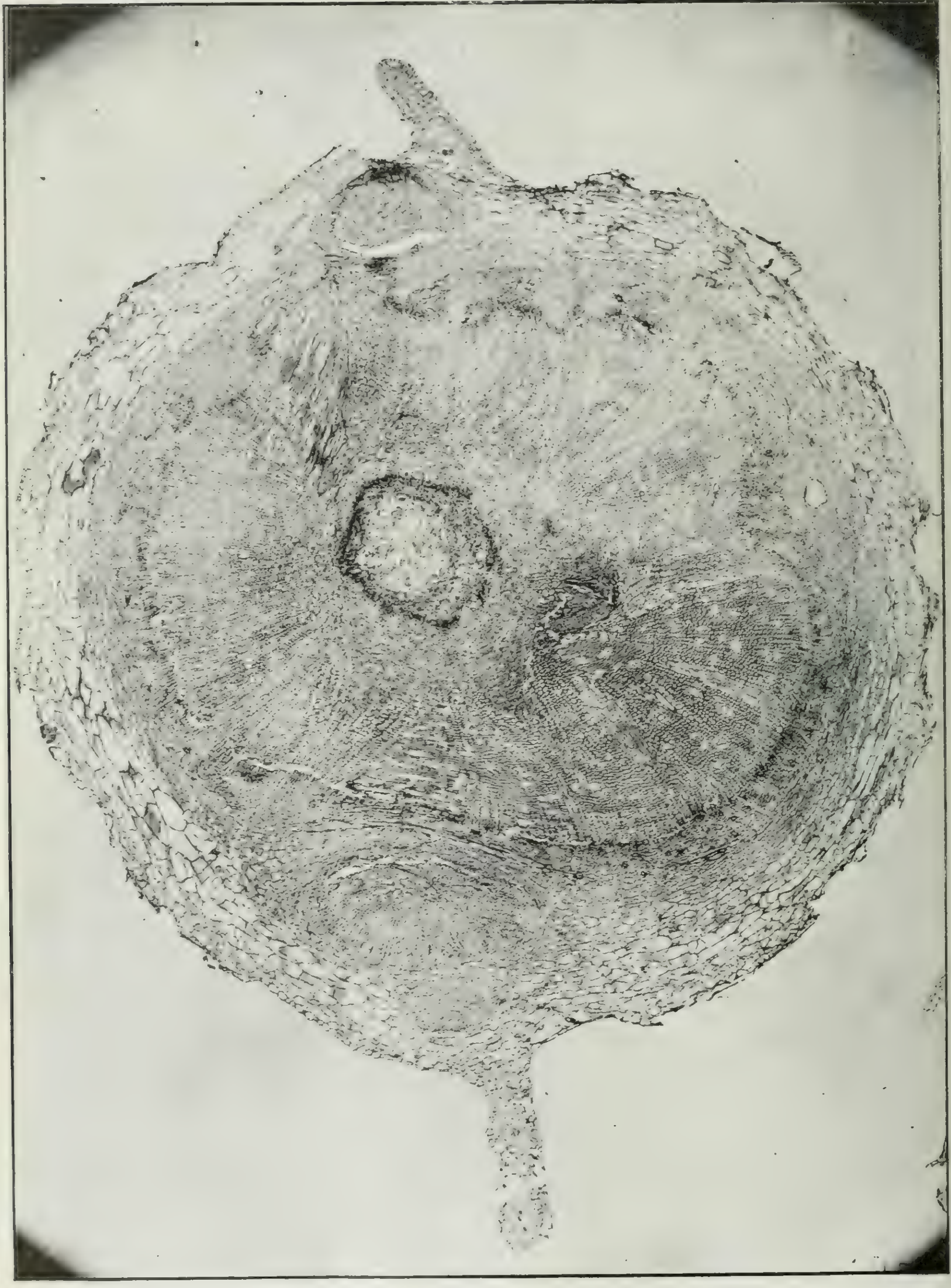
Daisy VII. Part of plant, showing primary and secondary tumors (p. 31).



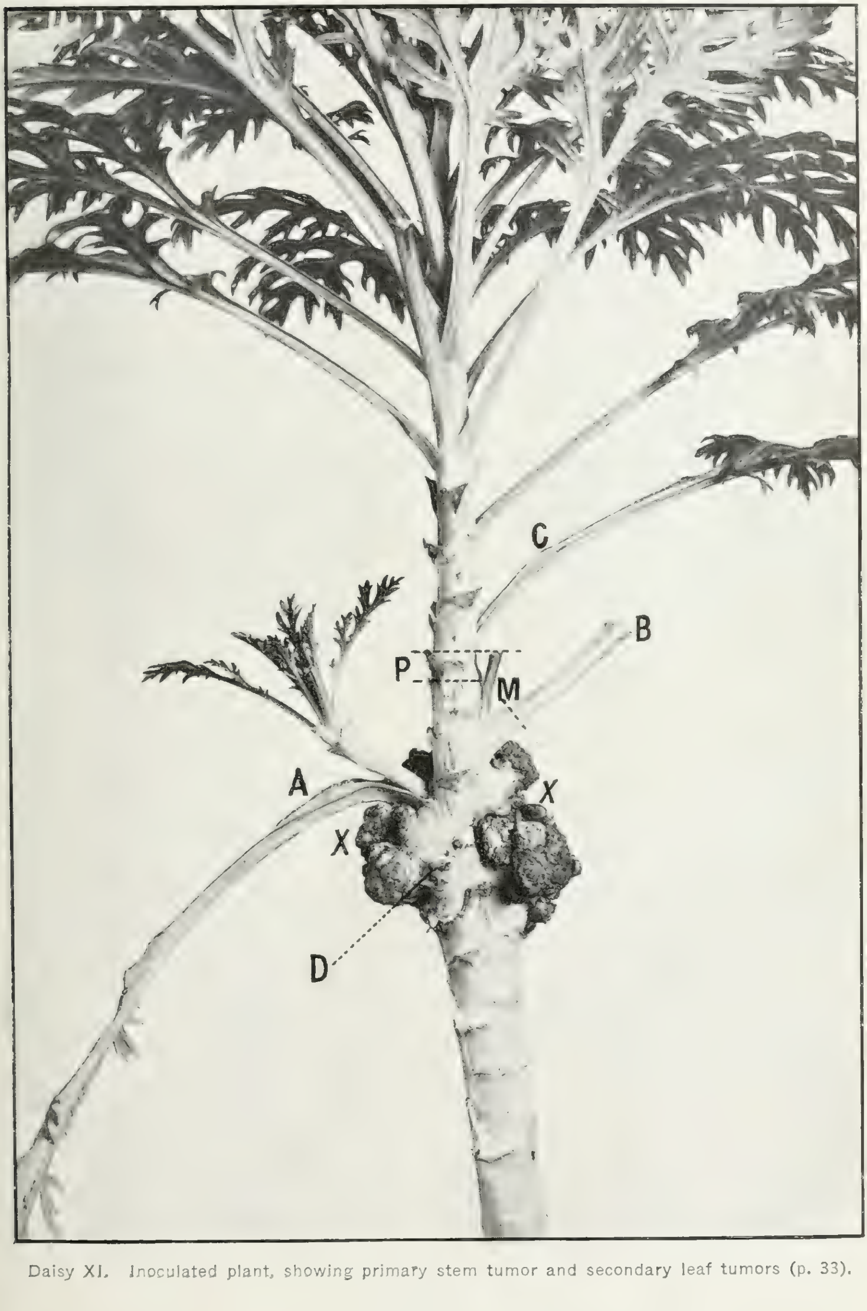
Daisy VII. Cross section of base of petiole A, showing stem structure in three leaf-traces (p. 32).



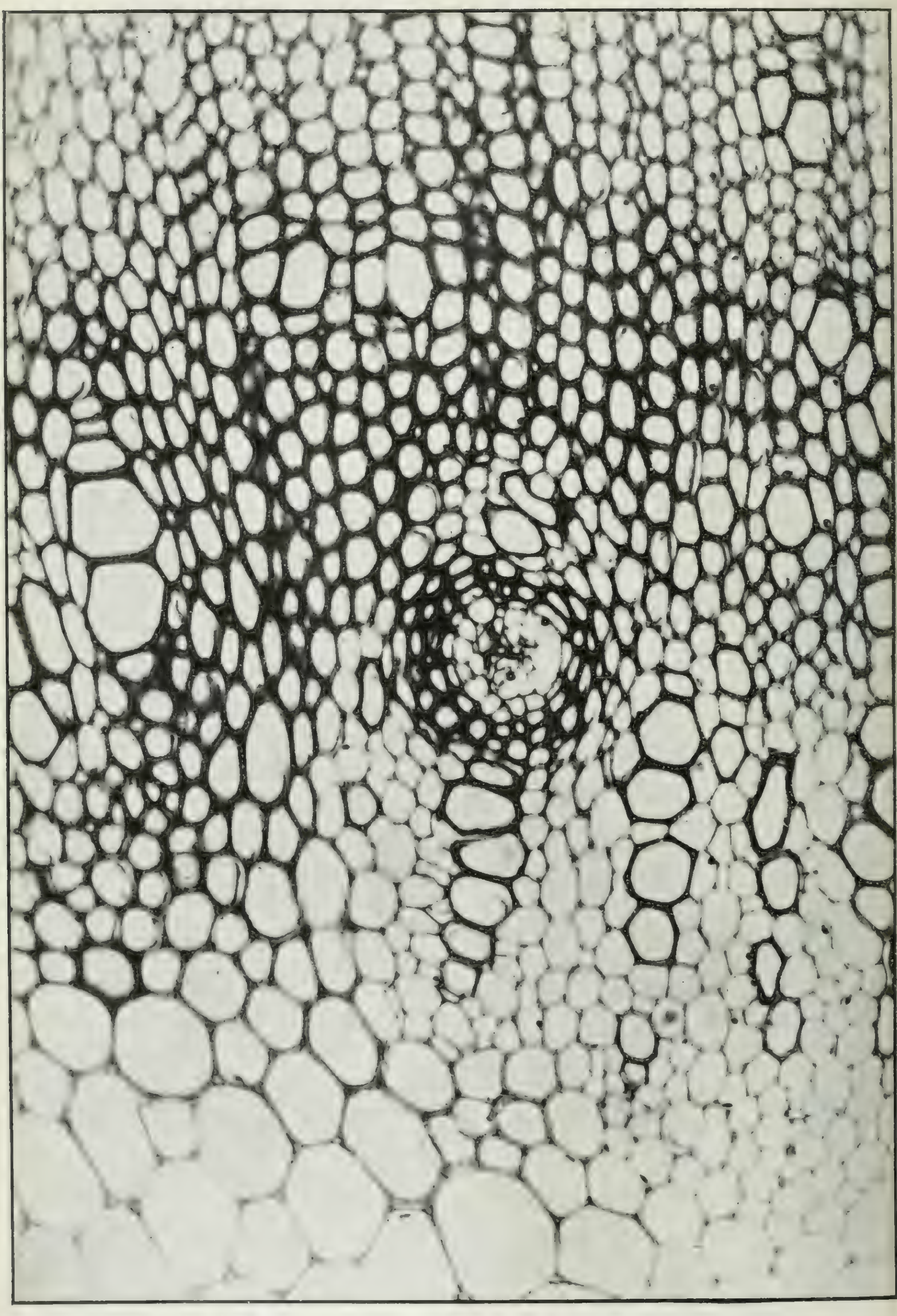
Daisy VIII. Cross section of the larger tumor-strand in petiole A; abnormal medullary ray in lower right corner (p. 33).



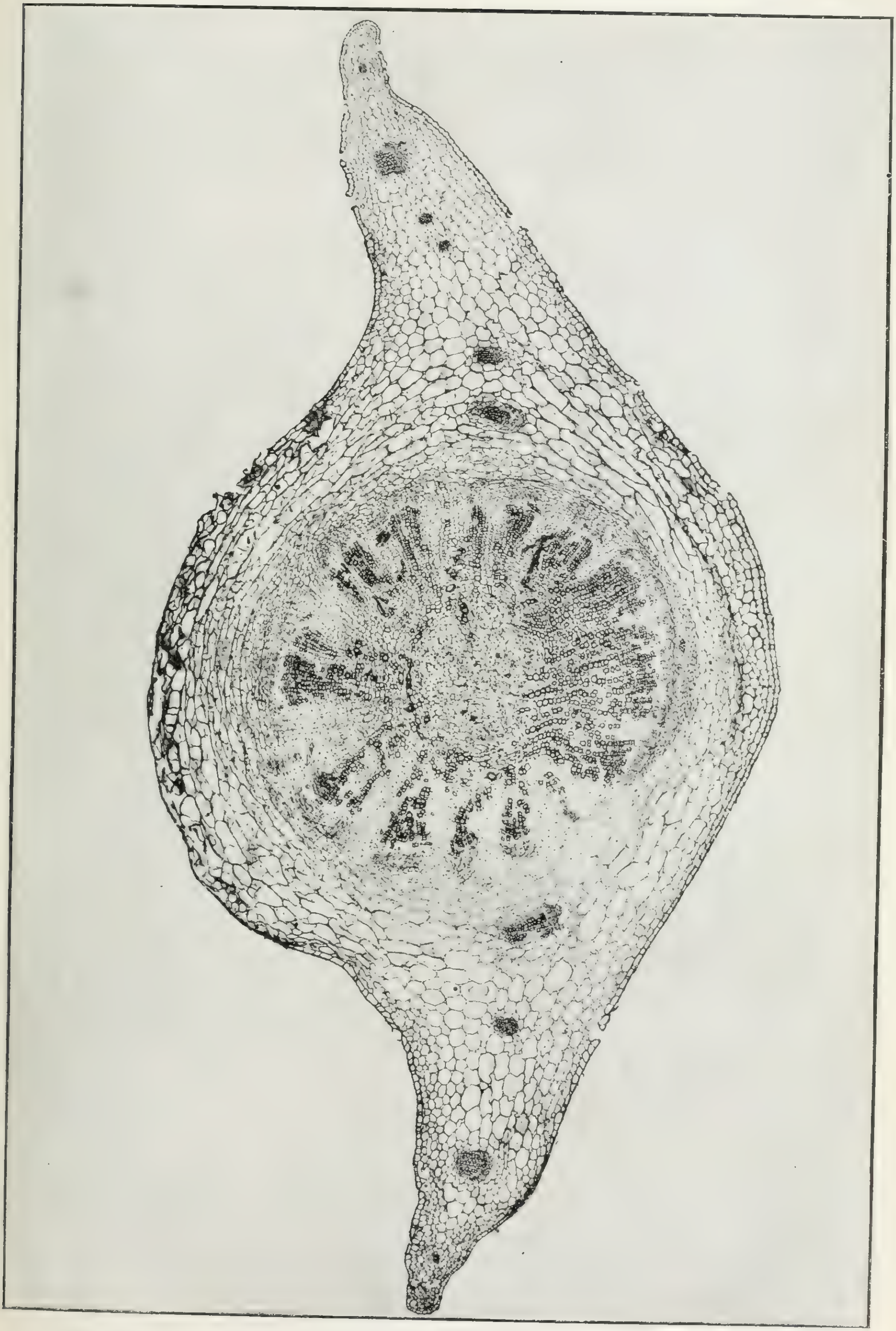
Daisy VII. Cross section of petiole D, showing stem structure (p. 33).



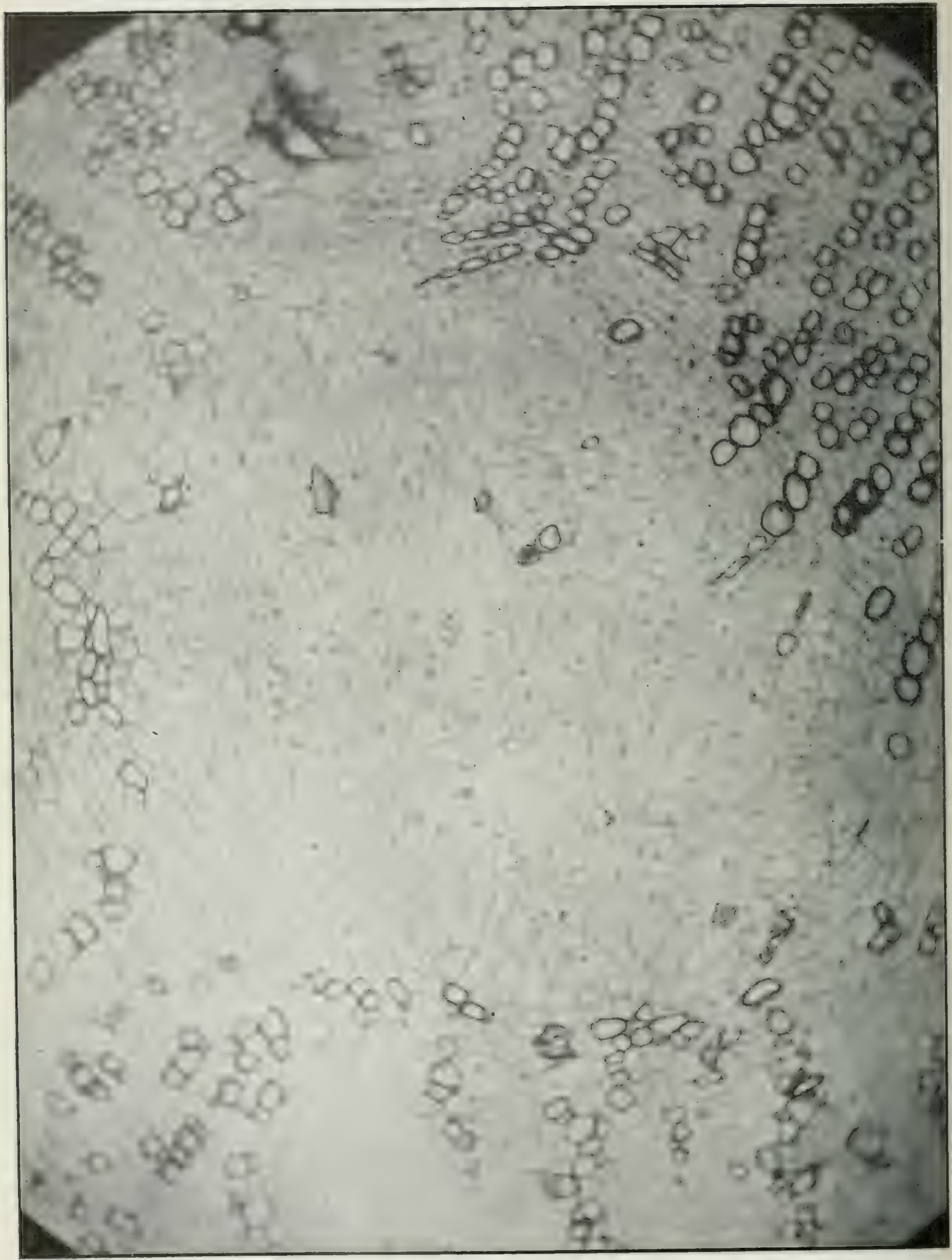
Daisy XI. Inoculated plant, showing primary stem tumor and secondary leaf tumors (p. 33).



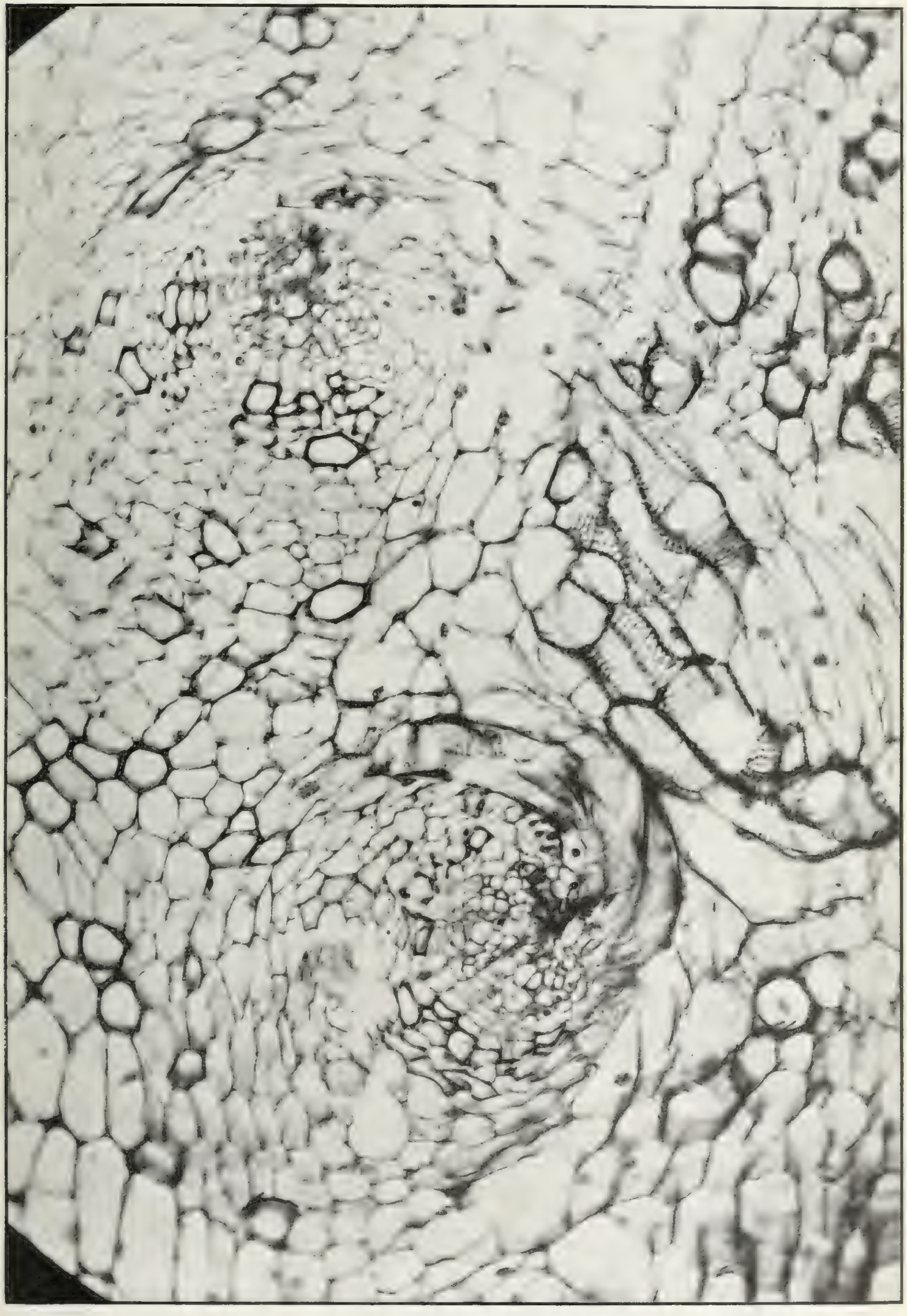
Daisy XI. Cross section of stem in vicinity of P, showing strand (p. 34).



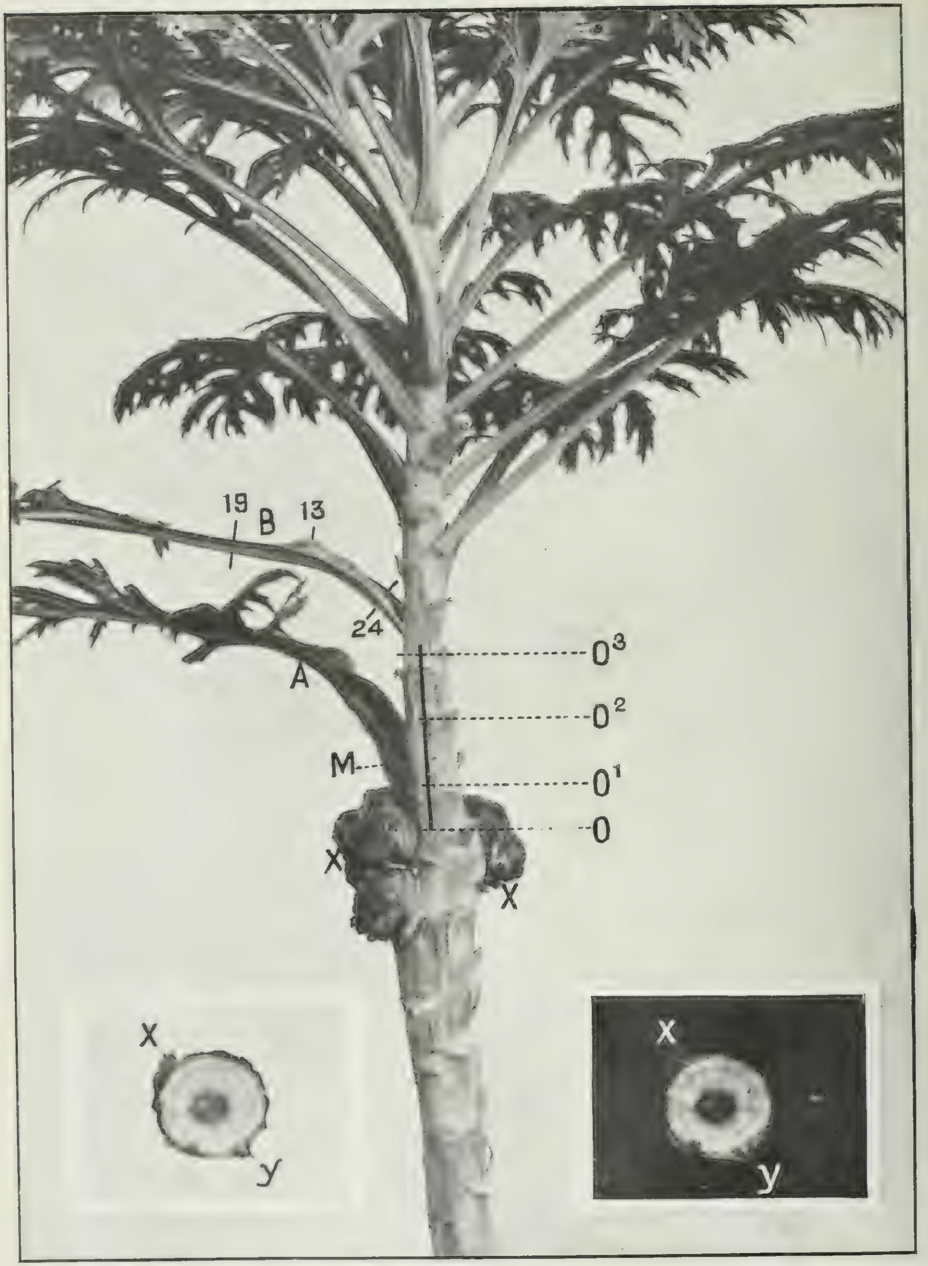
Daisy XI. Cross section of petiole B at M (Pl. XXXII), showing stem tumor in center (p. 34).



Daisy XI. Cross section of tumor-strand in center of Plate XXXIV, showing tracheids therein and torn and crushed spirals (p. 34).



Daisy XI. Whorls of tumor tissue and twisted tracheids in petiole B (p. 34).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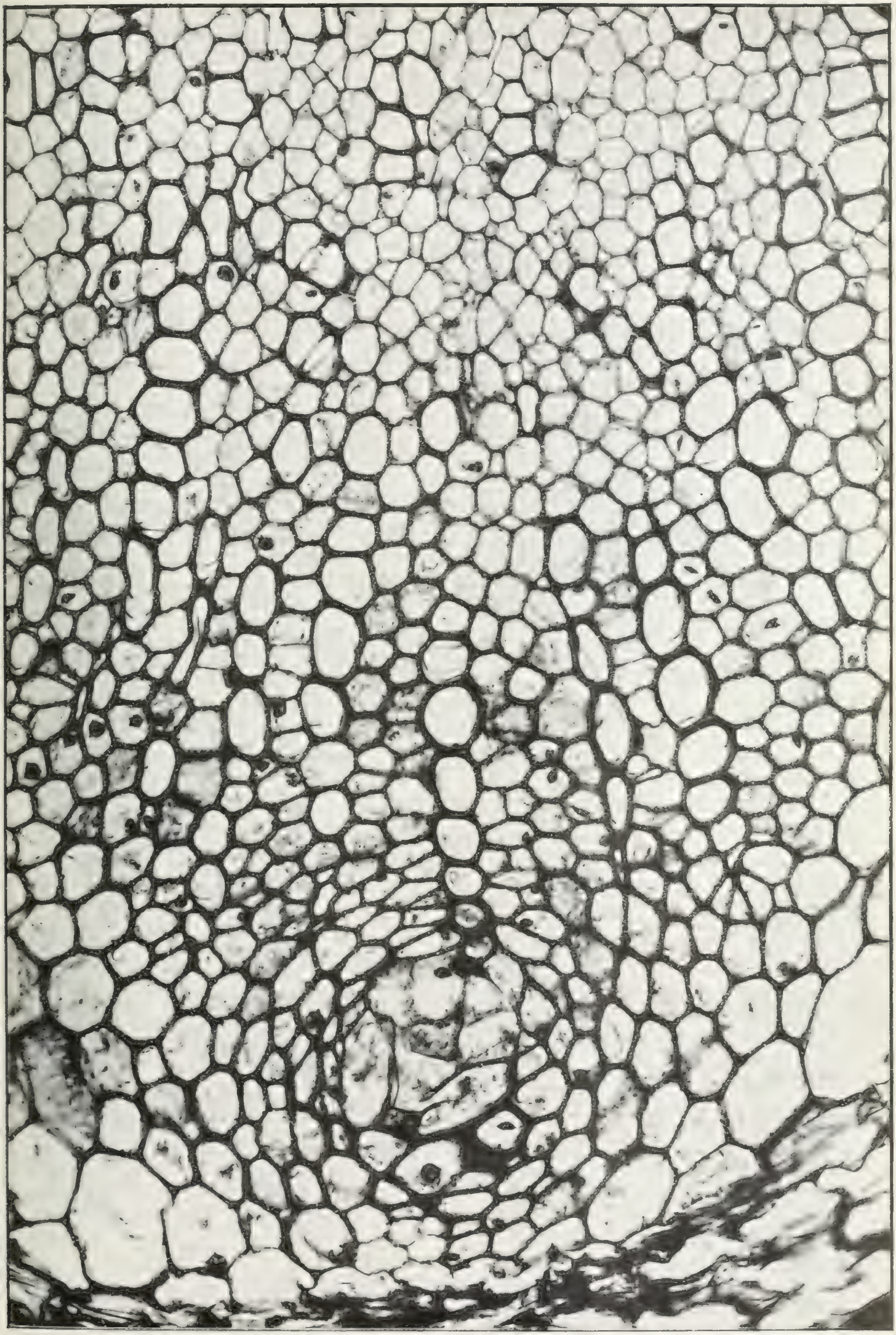
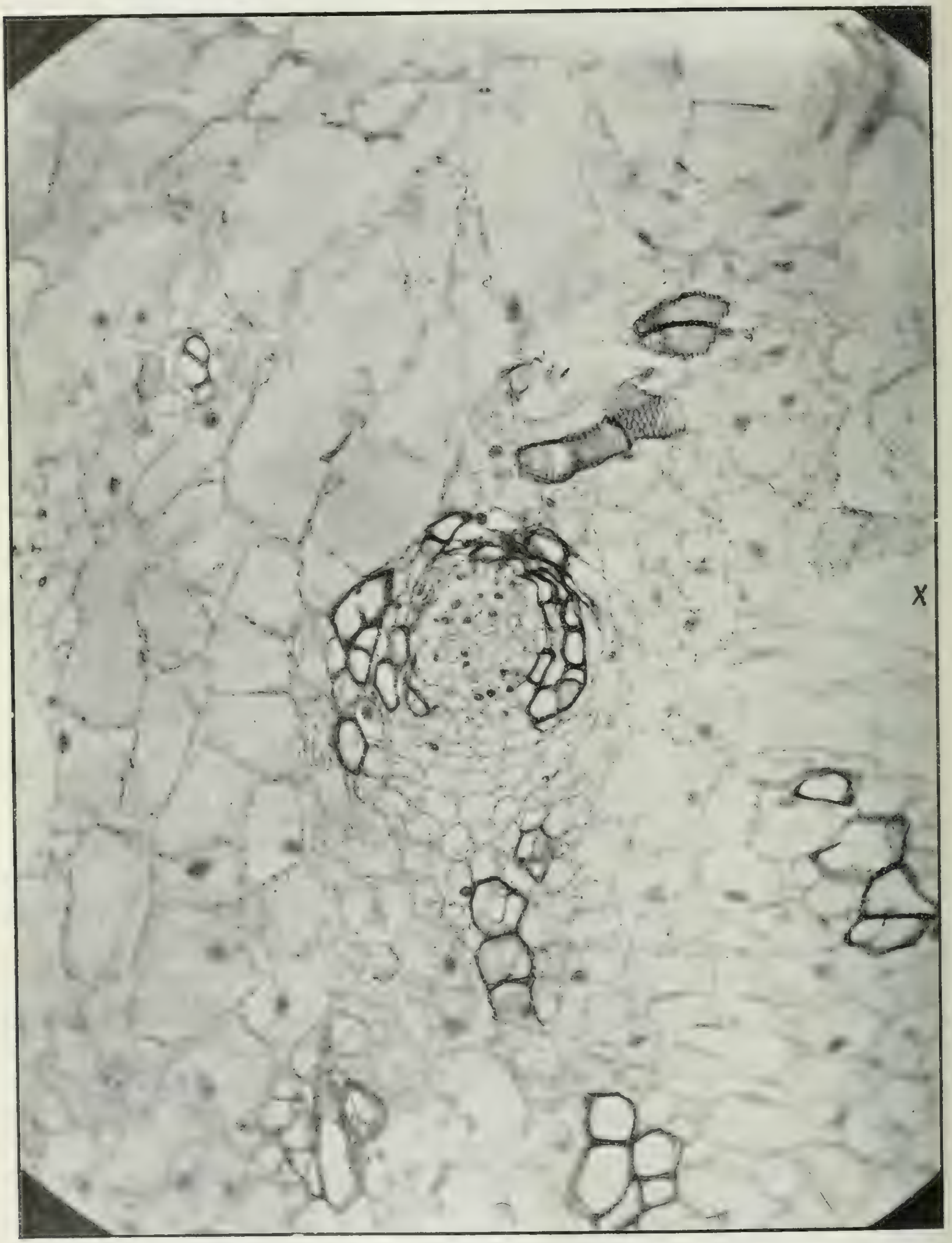
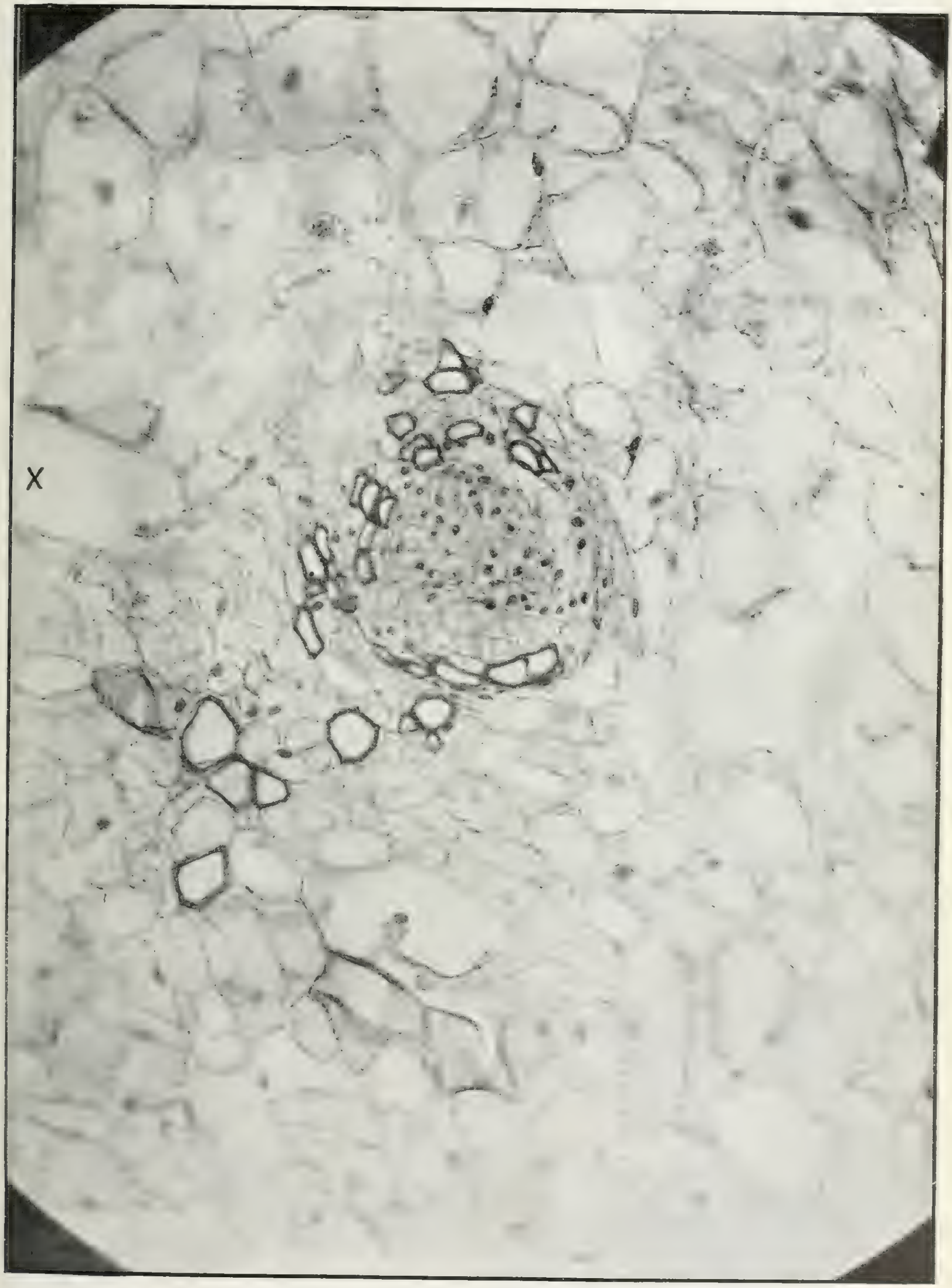
Daisy XII. Primary tumor and secondary tumors; also enlarged cross section of secondary tumor in a leaf (p. 35).



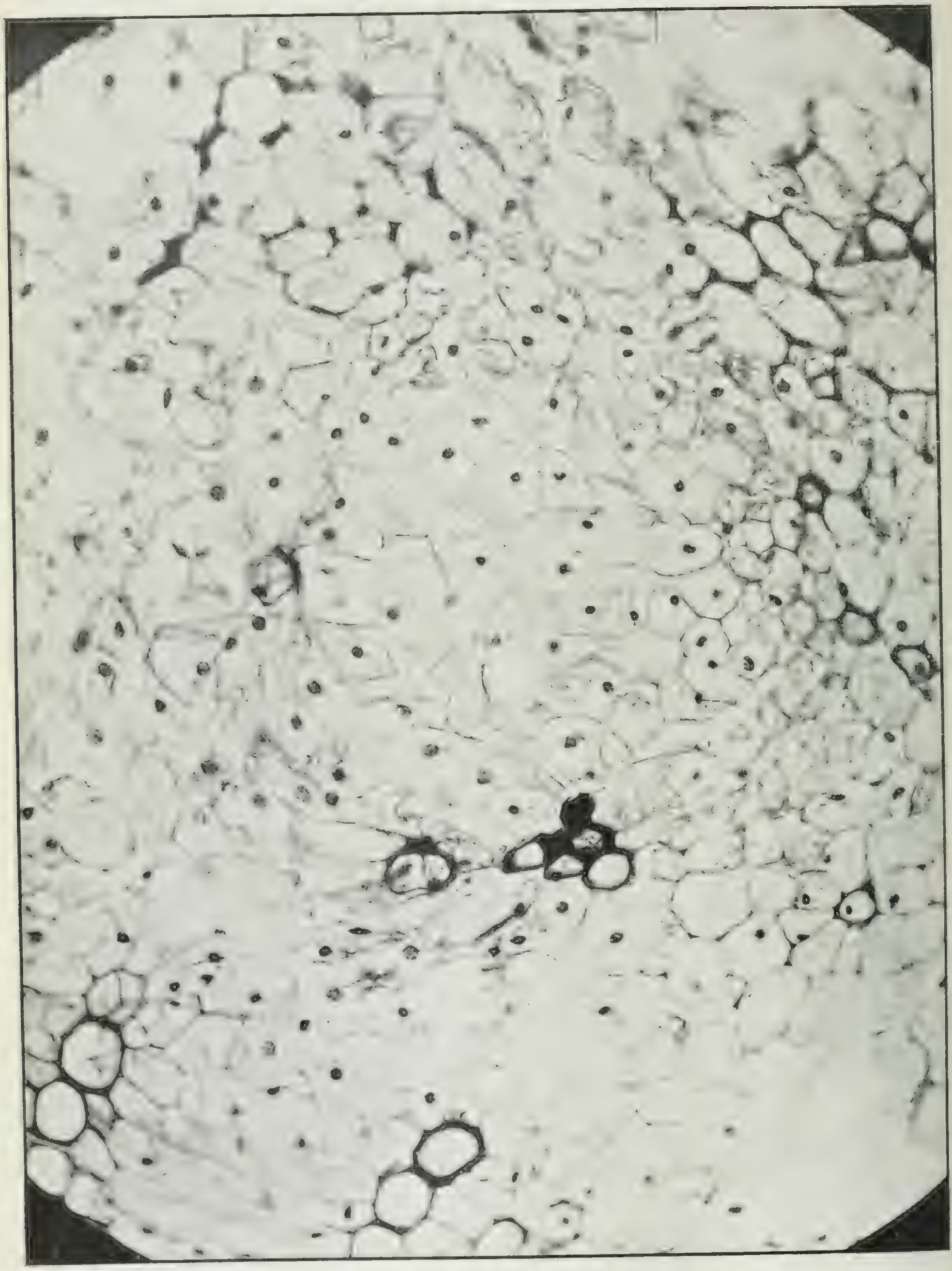
Daisy XII. Cross section of stem between tumors, showing tumor-strand (p. 35).



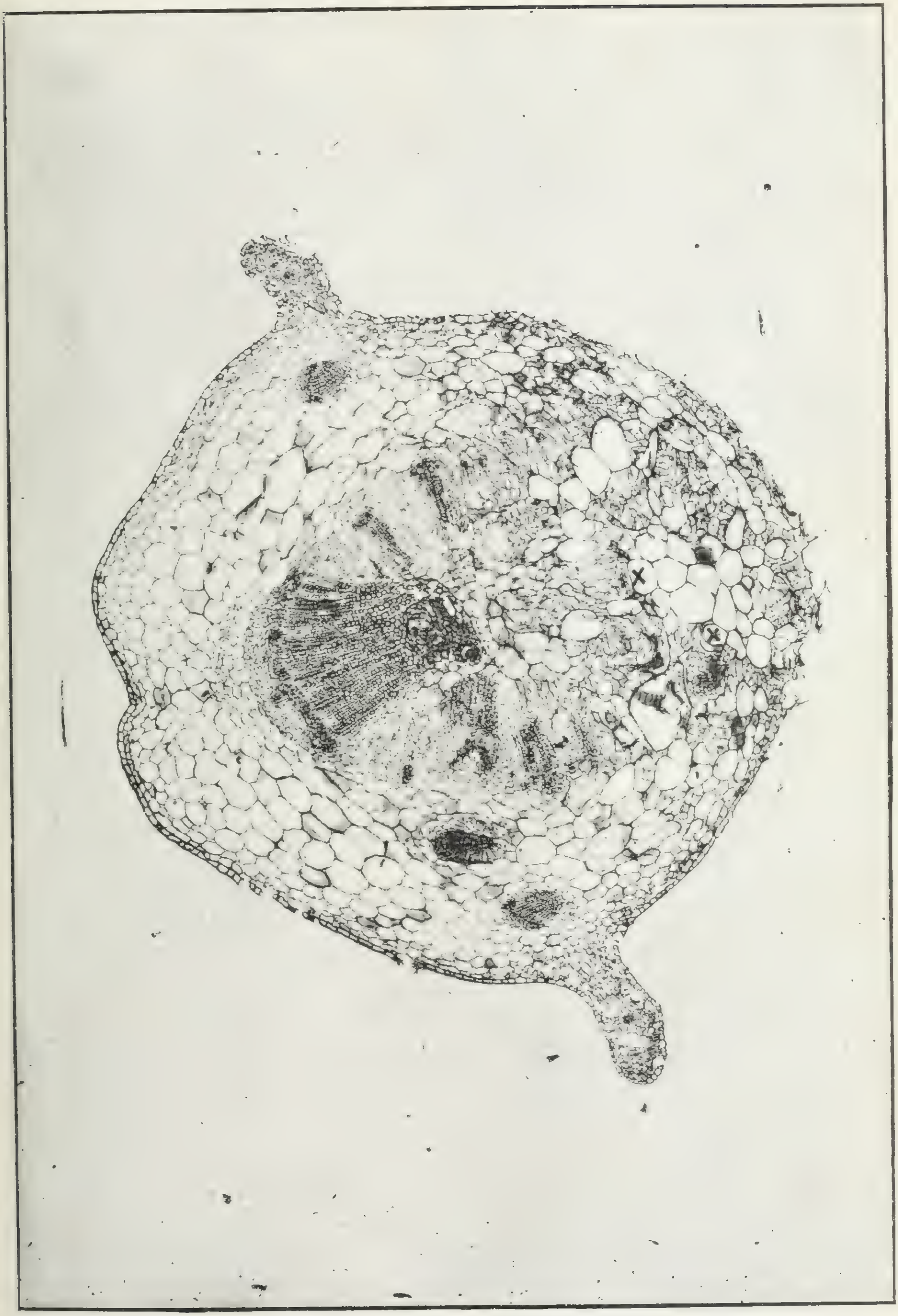
Daisy XII. Cross section of petiole A; whorl in tumor tissue (p. 36).



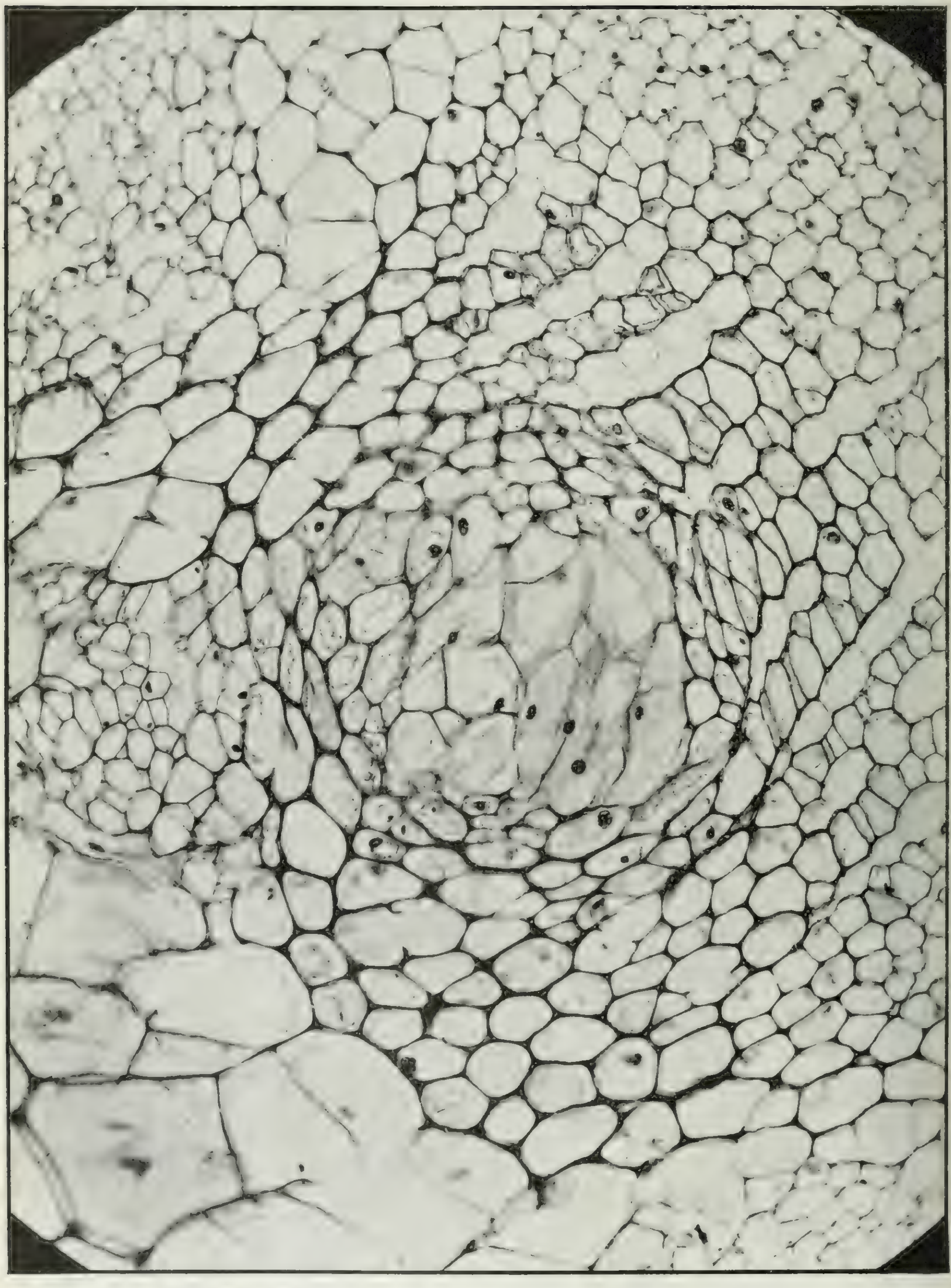
Daisy XII. Joins onto Plate XXXIX; another whorl in the tumor, X joins X (p. 36).



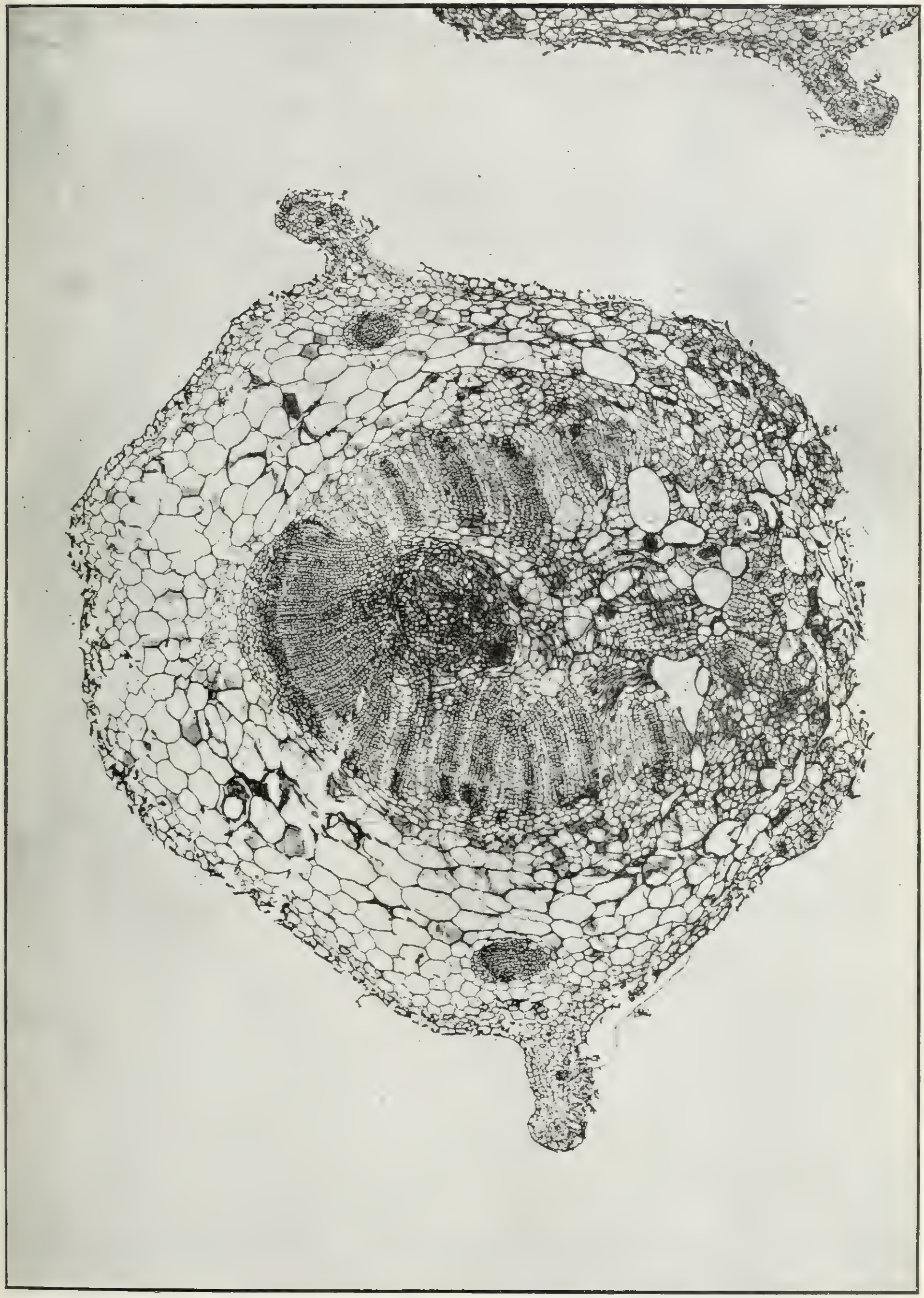
Daisy XII. Cross section of tumor-strand in petiole A, showing displaced vessels in the strand (p. 36).



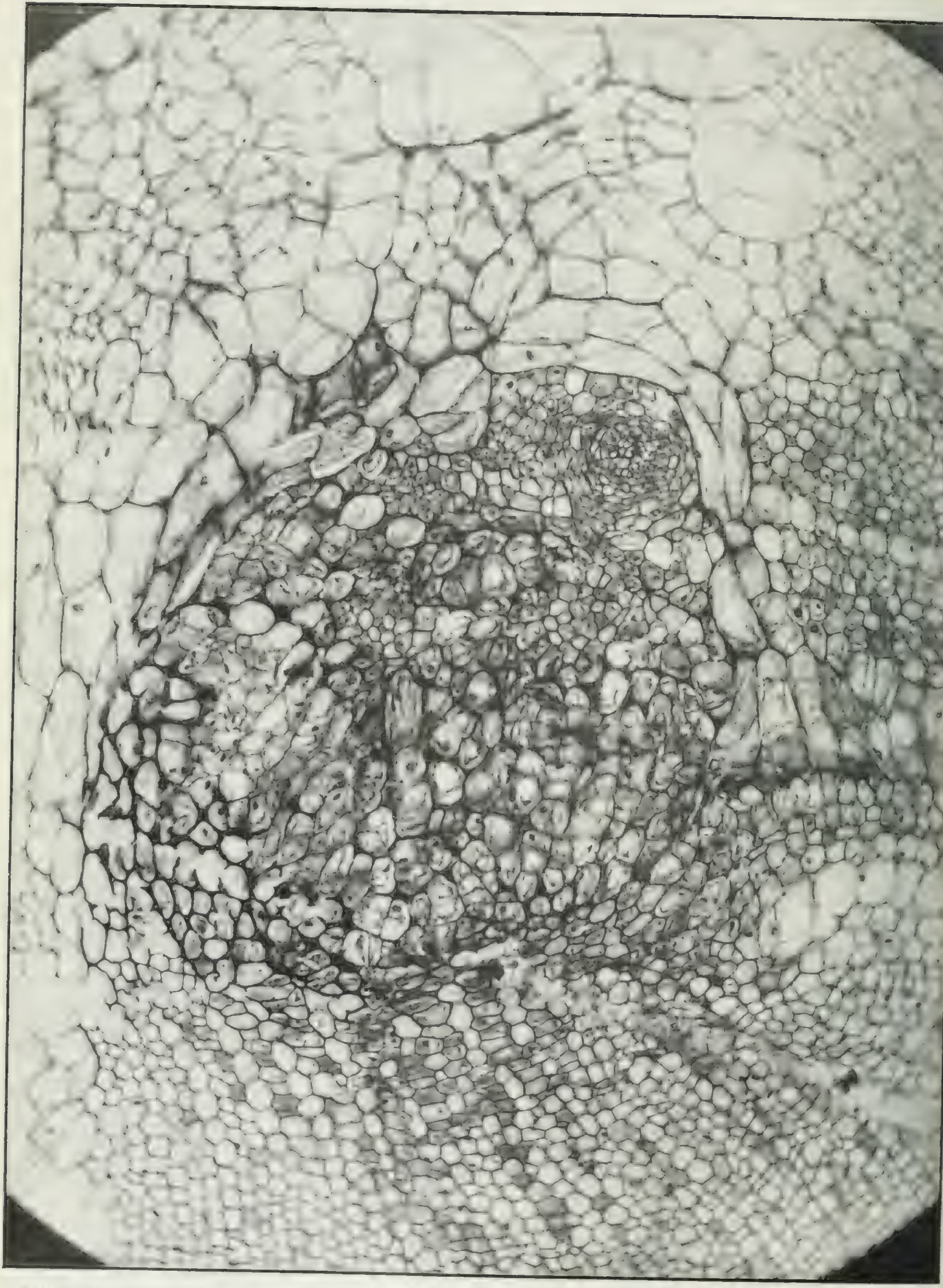
Daisy XII. Cross section of petiole B, showing a growing secondary tumor with cell inclusions (p. 36).



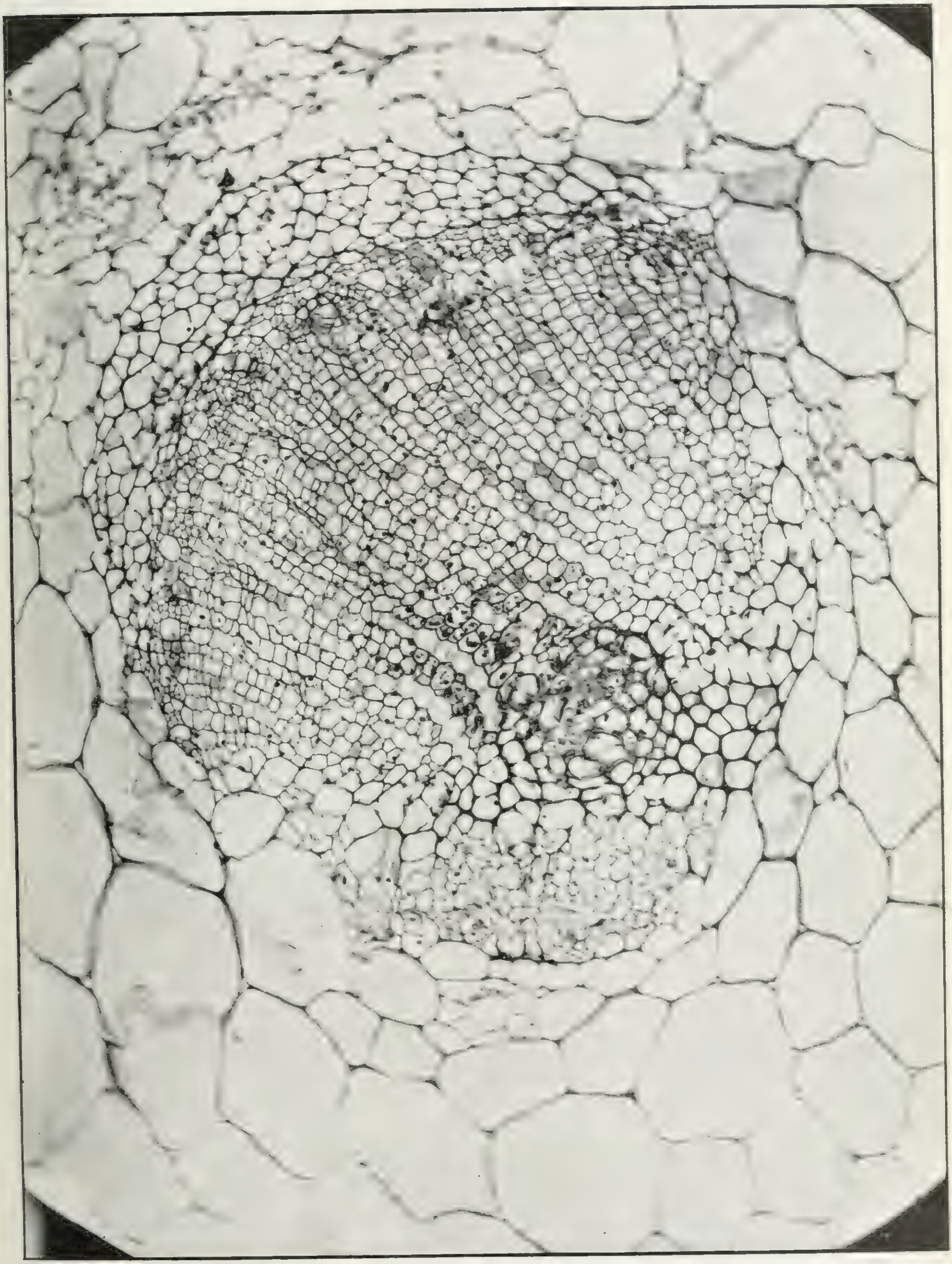
Daisy XII. Cross section, tumor-strand in petiole B, near XLII (p. 37).



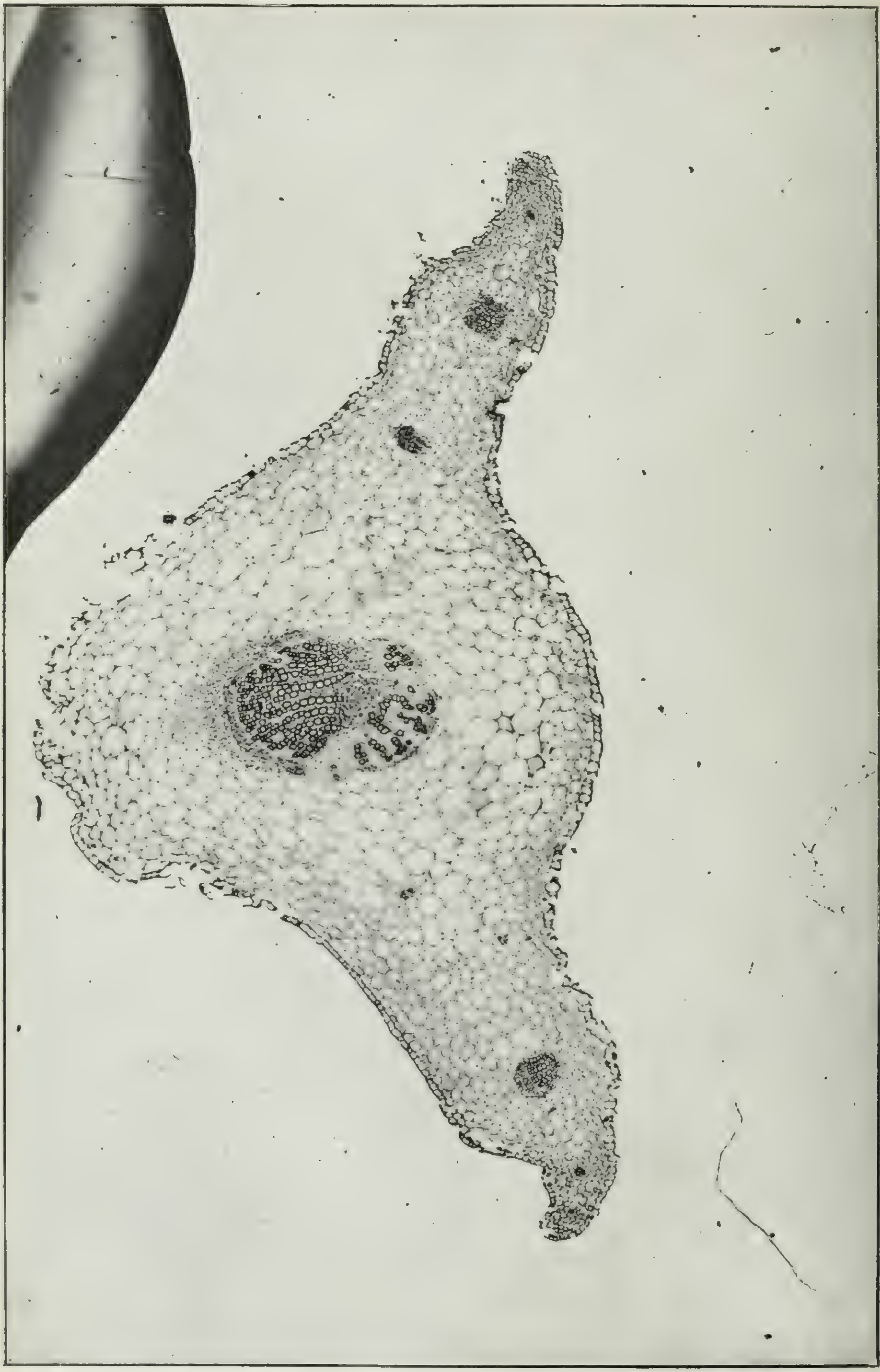
Daisy XII. Cross section of petiole B at another level, showing cell inclusions and large tumor-strand, with normal part of leaf-trace at left (p. 37).



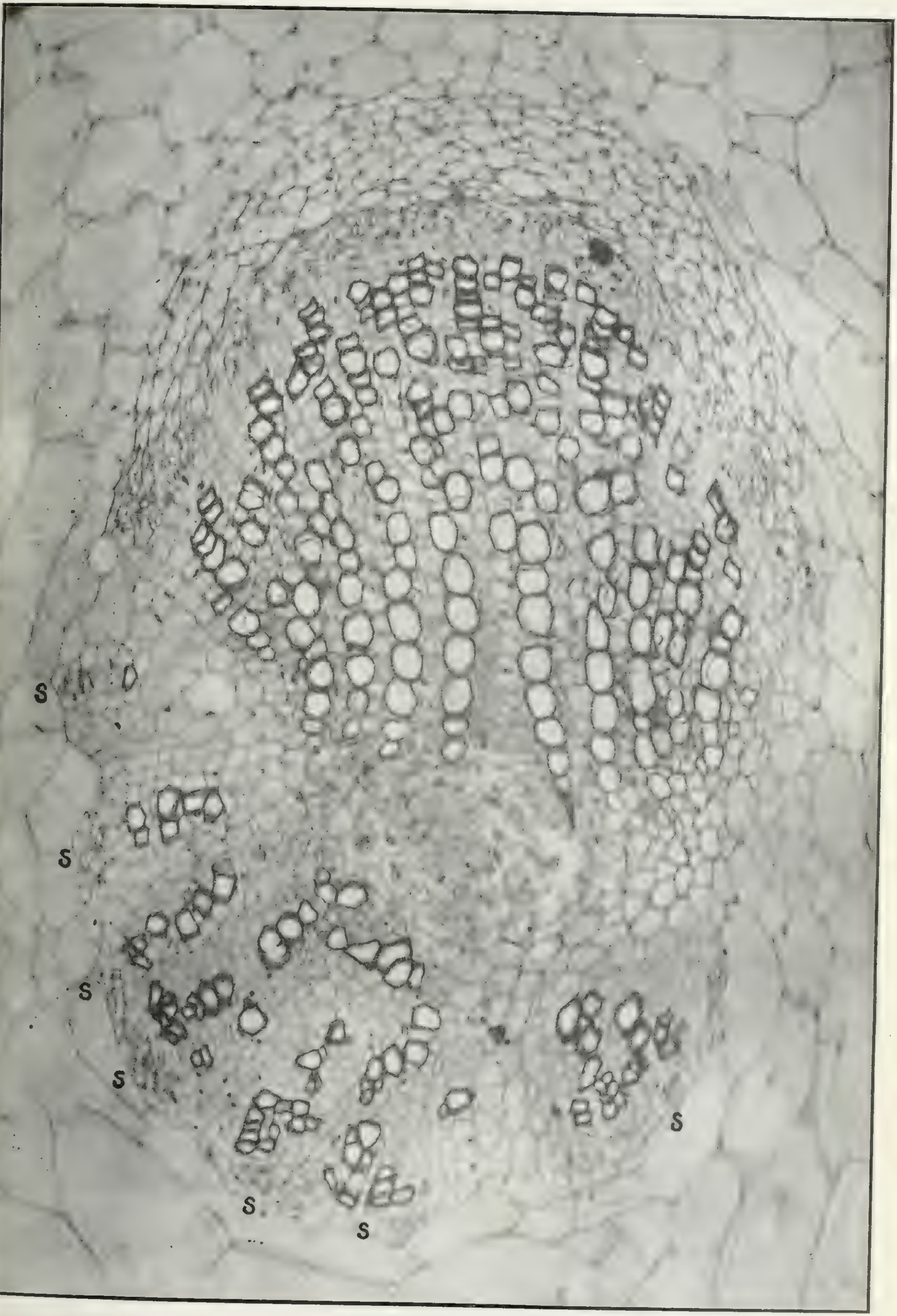
Daisy XII. Tumor-strand from Plate XLIV; large and small cells present; abnormal medullary ray at right (p. 37).



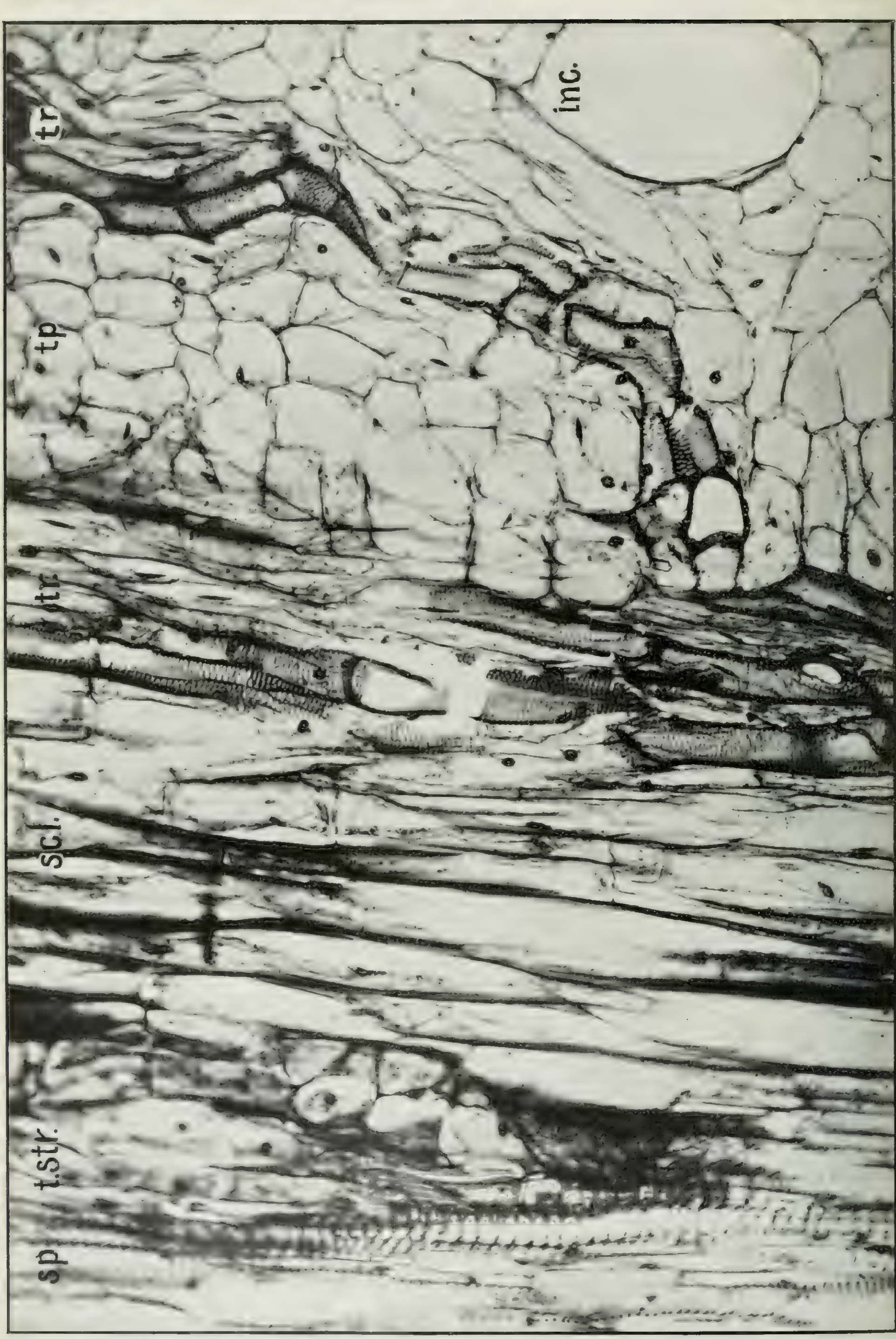
Daisy XII. Infected leaf-trace far out on petiole B (p. 37).



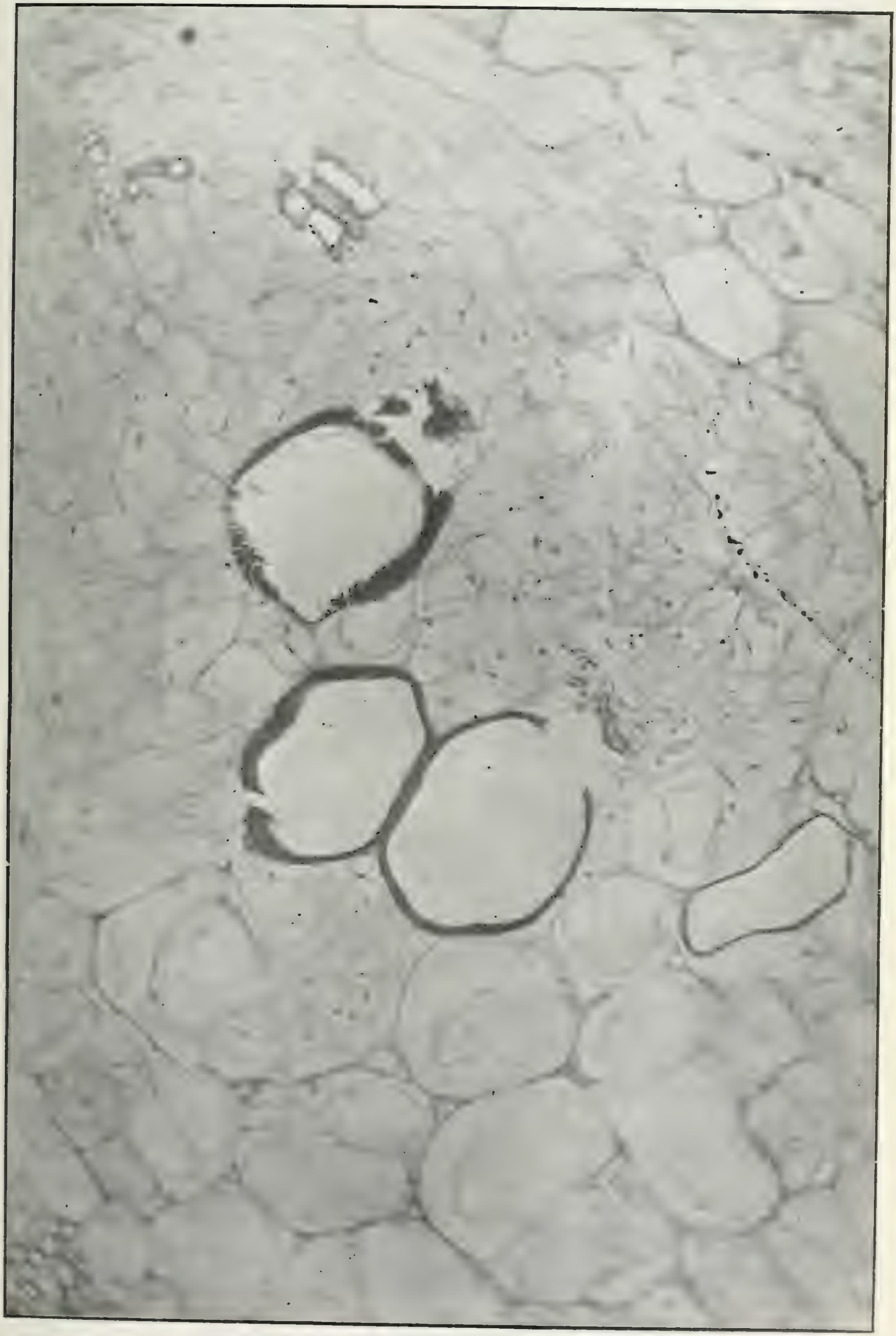
Daisy XII. Cross section of lower part of petiole B, showing incipient tumor in the central leaf-trace (p. 38).



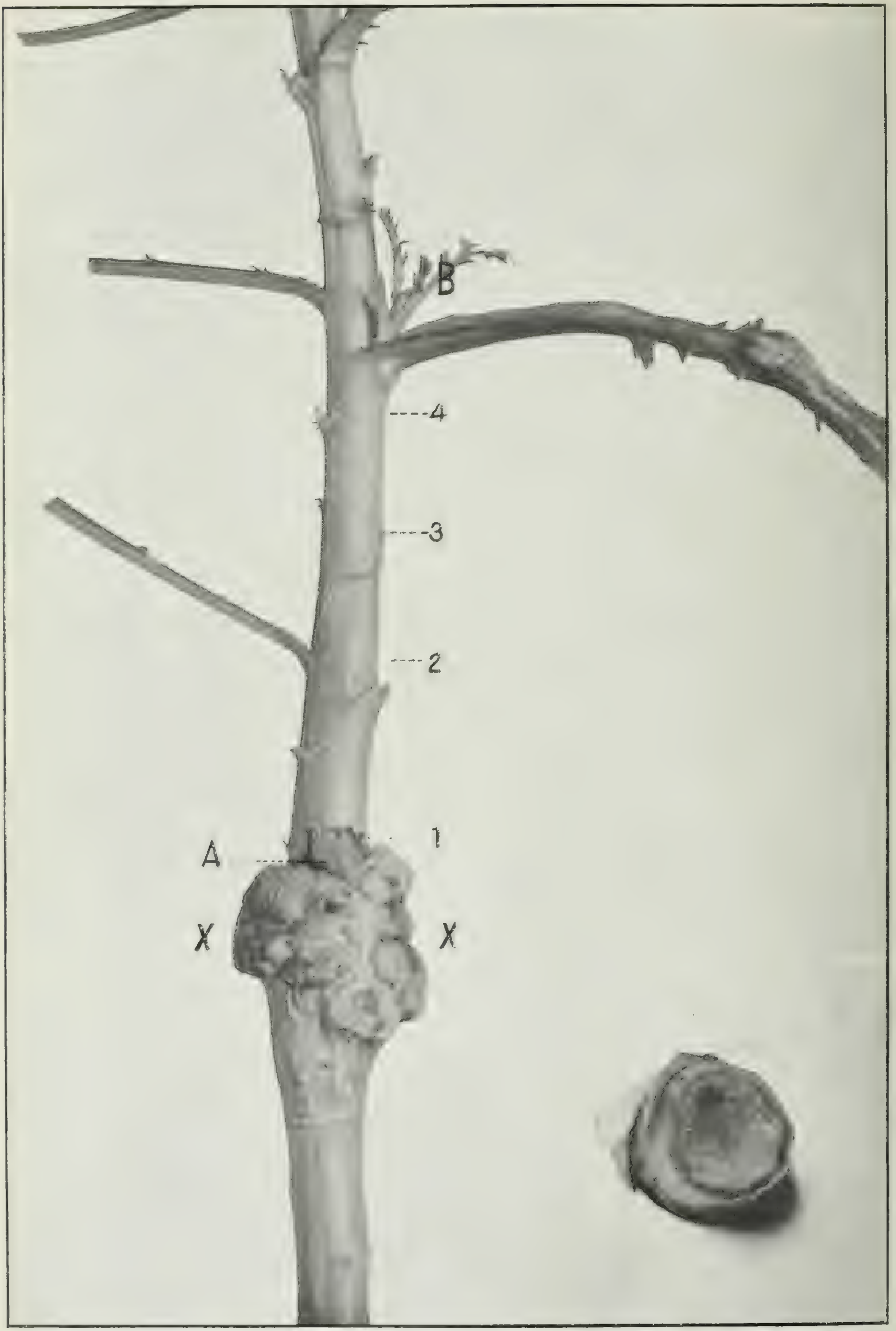
Daisy XII. Cross section of central leaf-trace of petiole B, further enlarged for comparison with Plate III (p. 38).


tr.
tp
tr.
scl.
t.str.
sp
inc.

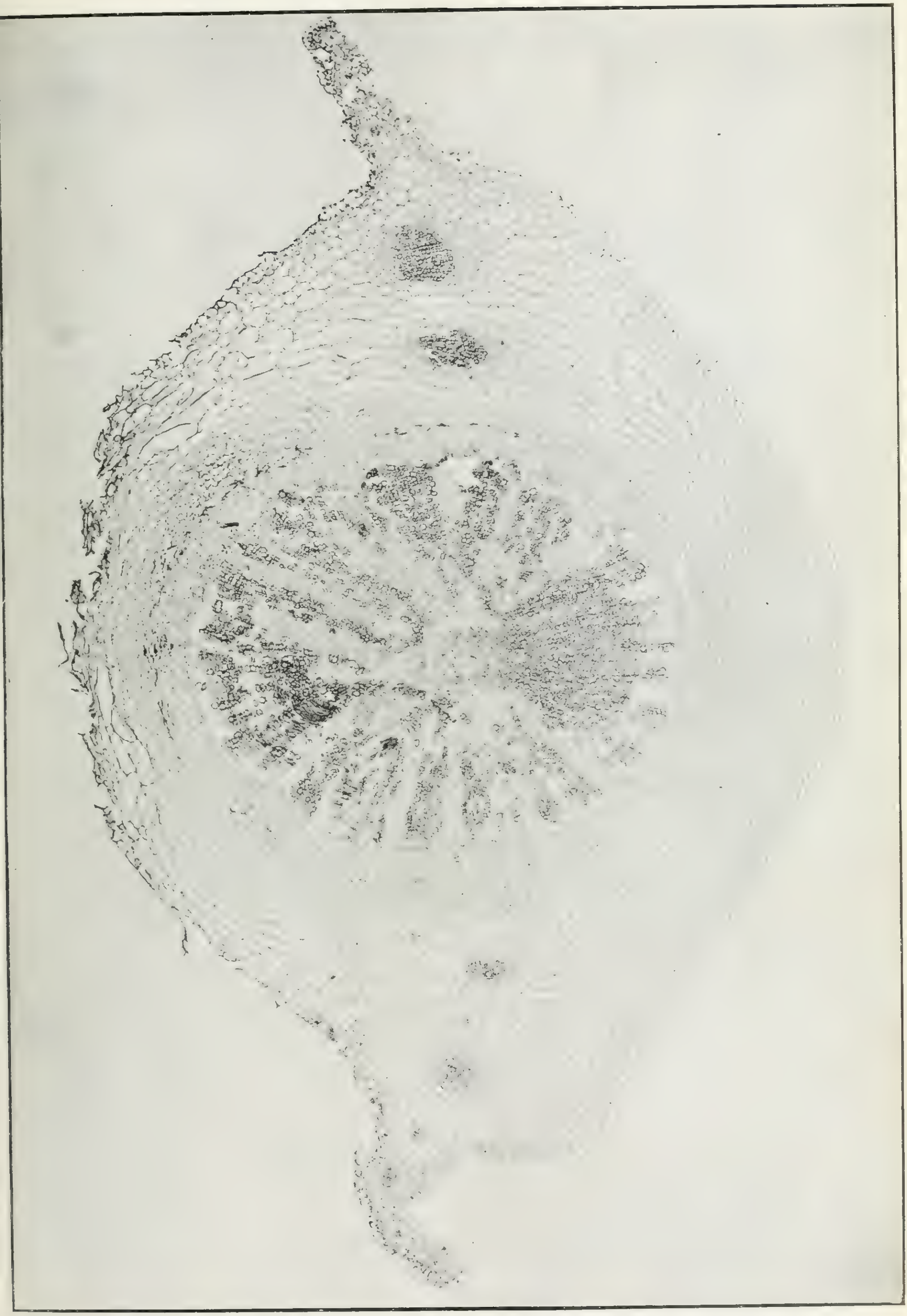
Daisy XII. Longitudinal section of leaf-trace shown in Plate XLVIII, all abnormal except sp and scl (p. 38).



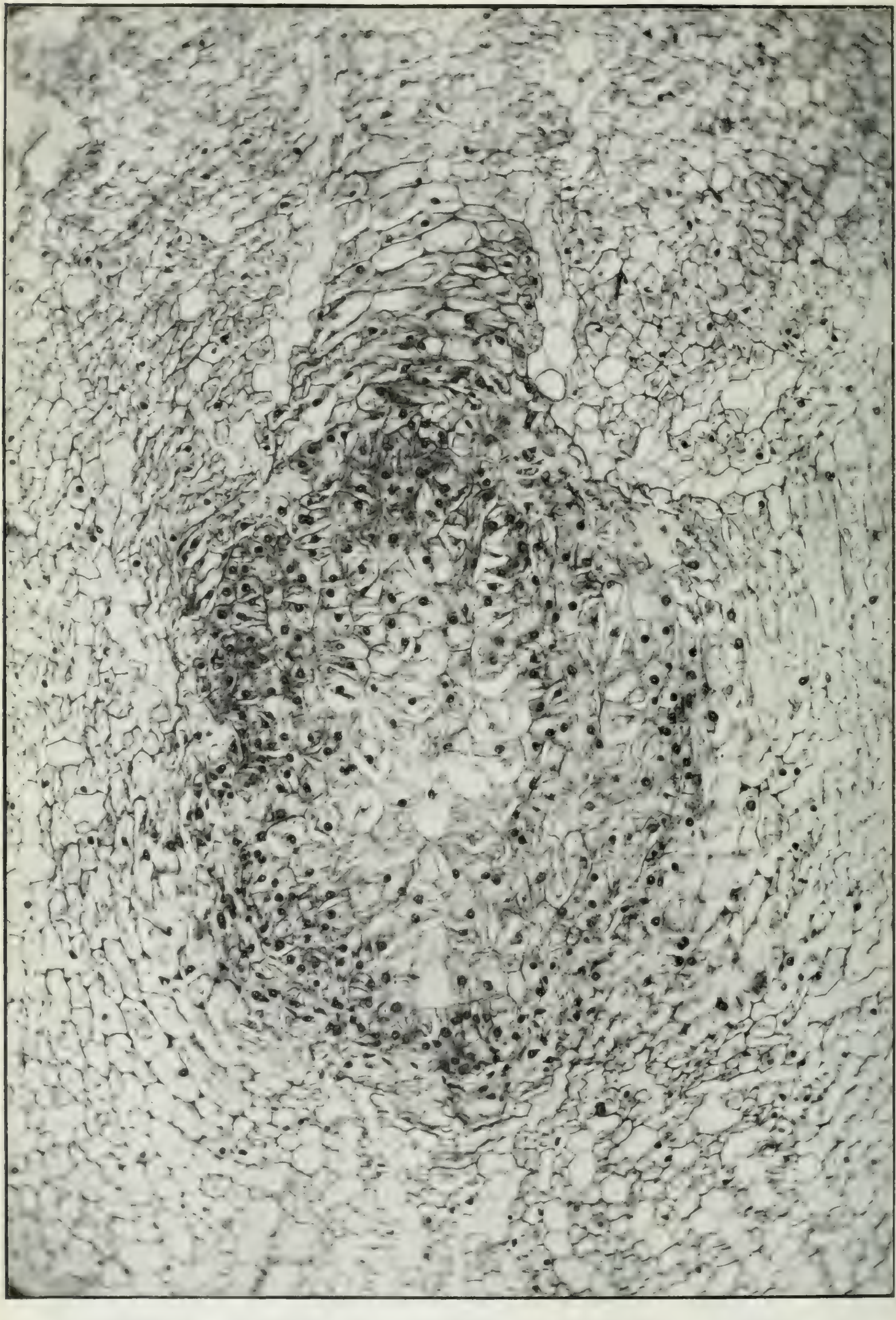
Daisy XII. Cross section showing abnormal lignification of cell-walls in the tumor. [illegible]



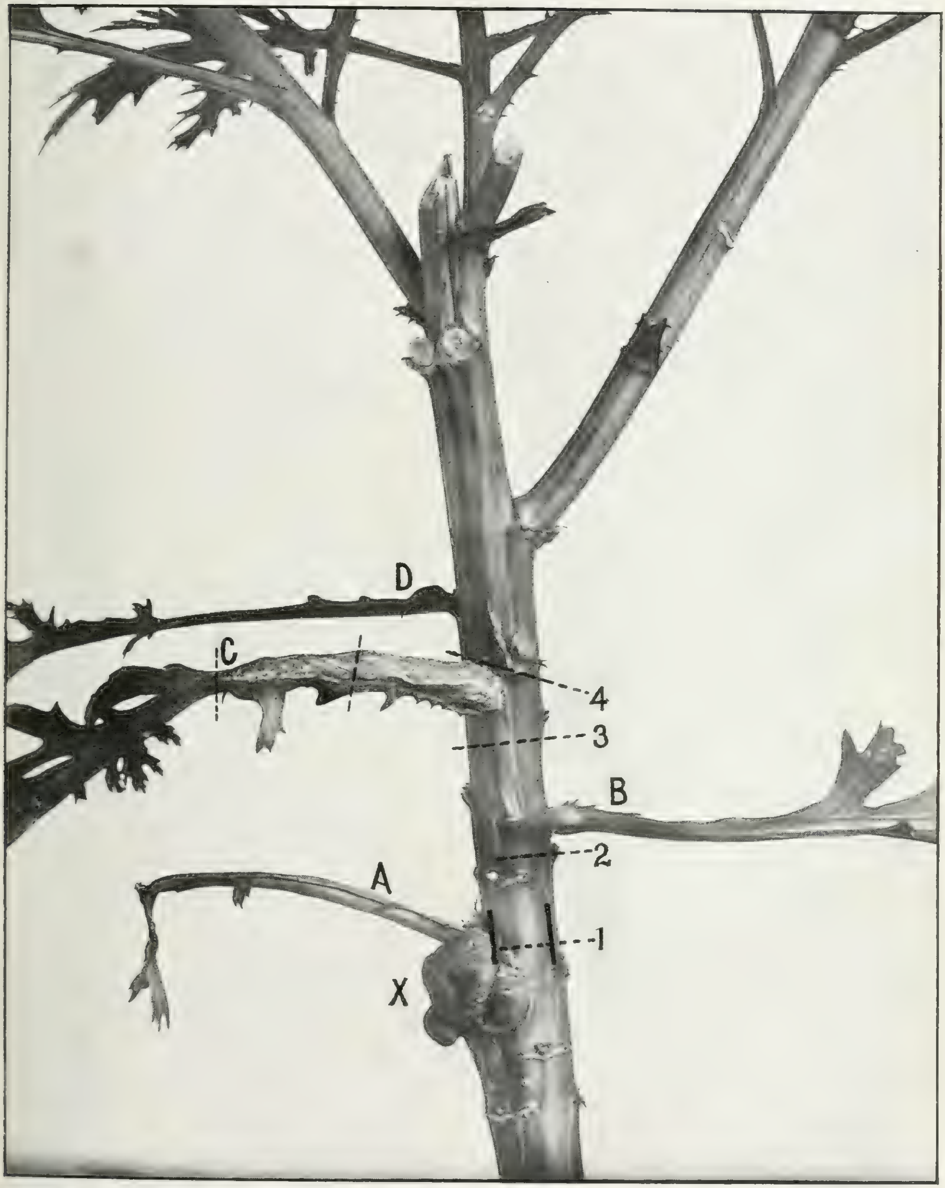
Daisy XIII. Inoculated plant, showing primary stem tumor and secondary leaf tumors; also section of stem at fig. 2 (p. 39).



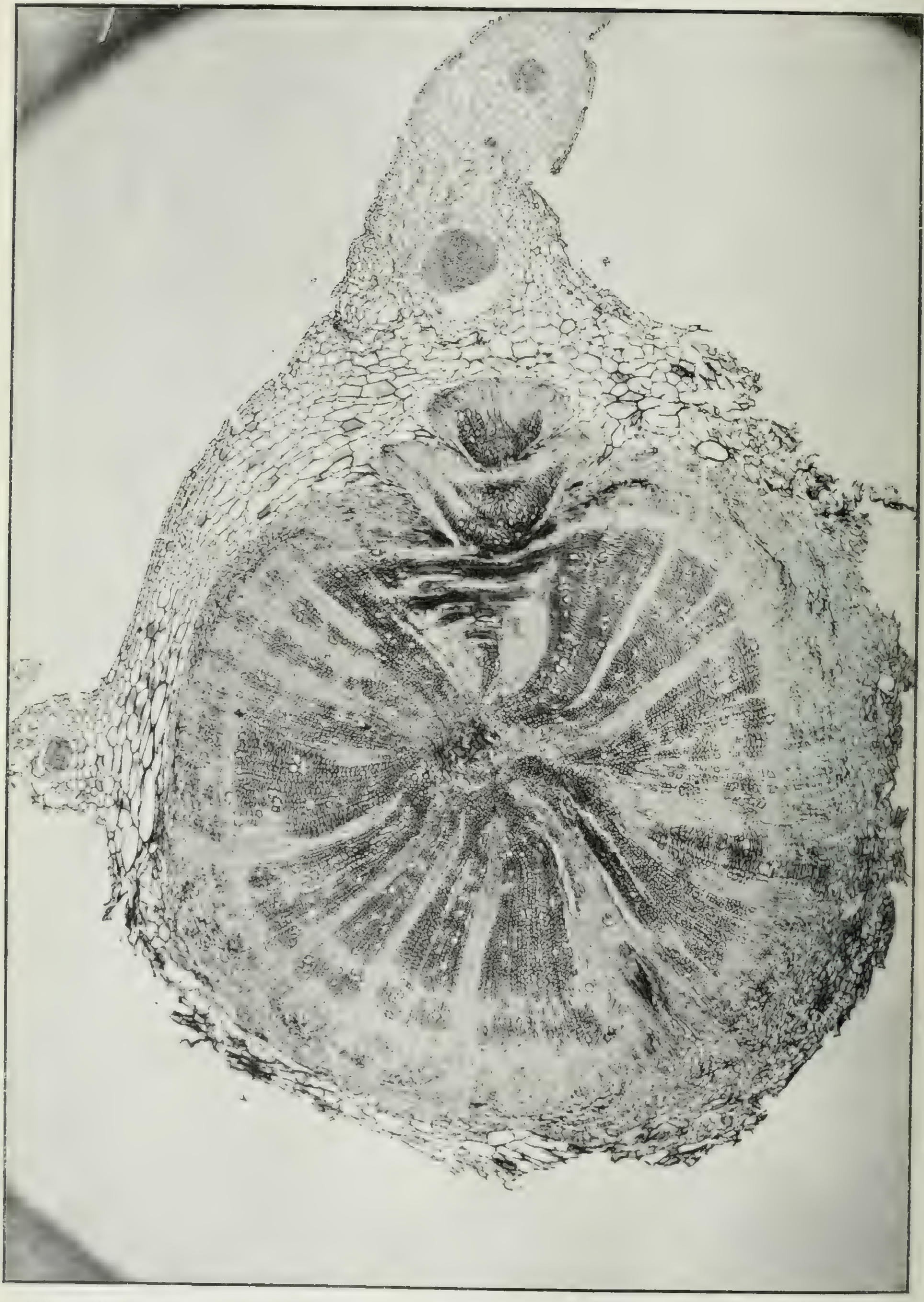
Daisy XIII. Cross section of petiole B, showing young secondary tumor in leaf-trace (p. 39).



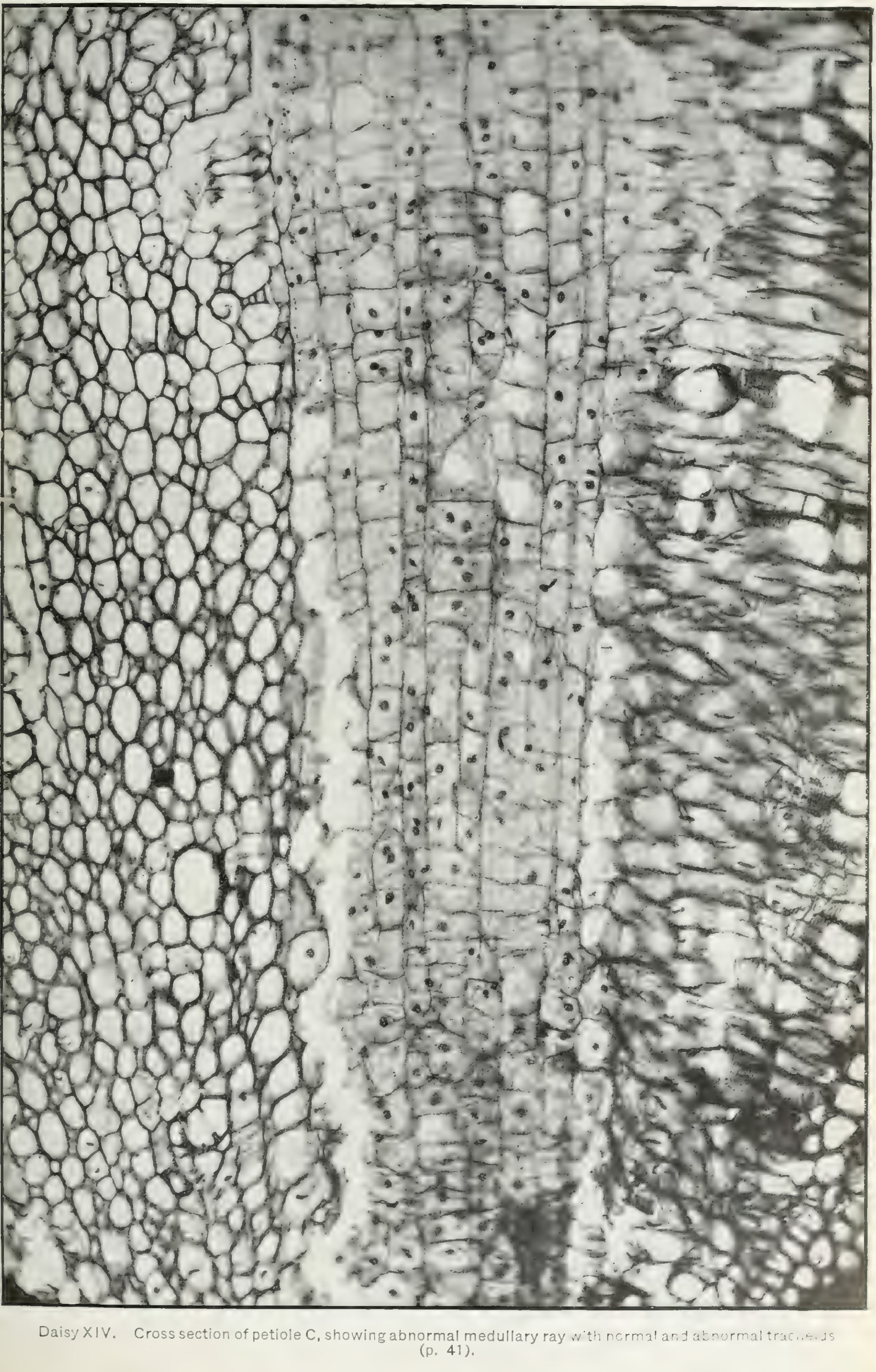
Daisy XIII. Tumor-strand enlarged from Plate LII, nuclei deeply stained (p. 40).



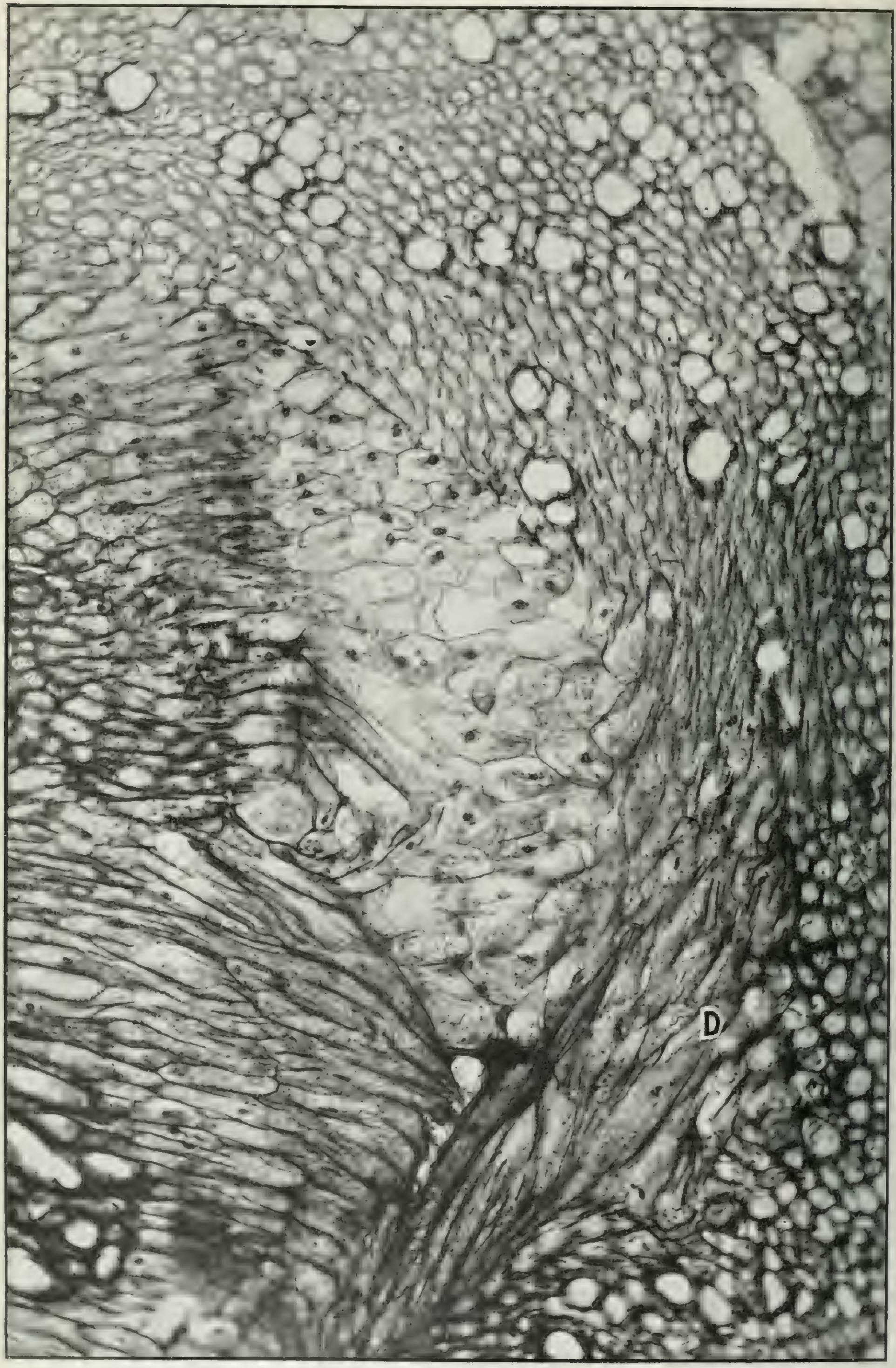
Daisy XIV. Portion of inoculated plant, showing primary stem tumor and secondary leaf tumors (p. 40).



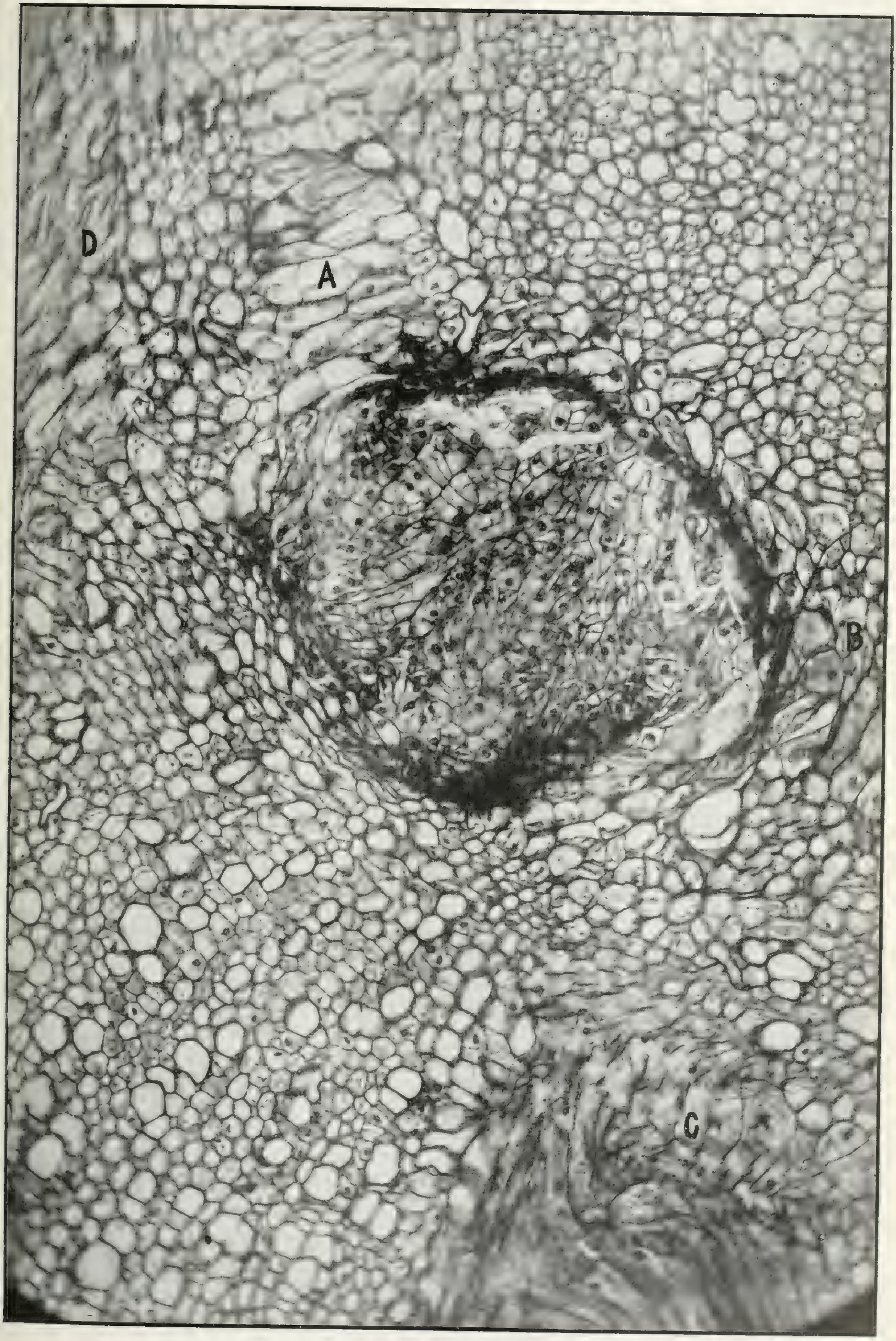
Daisy XIV. Cross section of petiole C, showing secondary tumor with stem structure. What remains of the normal tissue is above and at the left (p. 40).



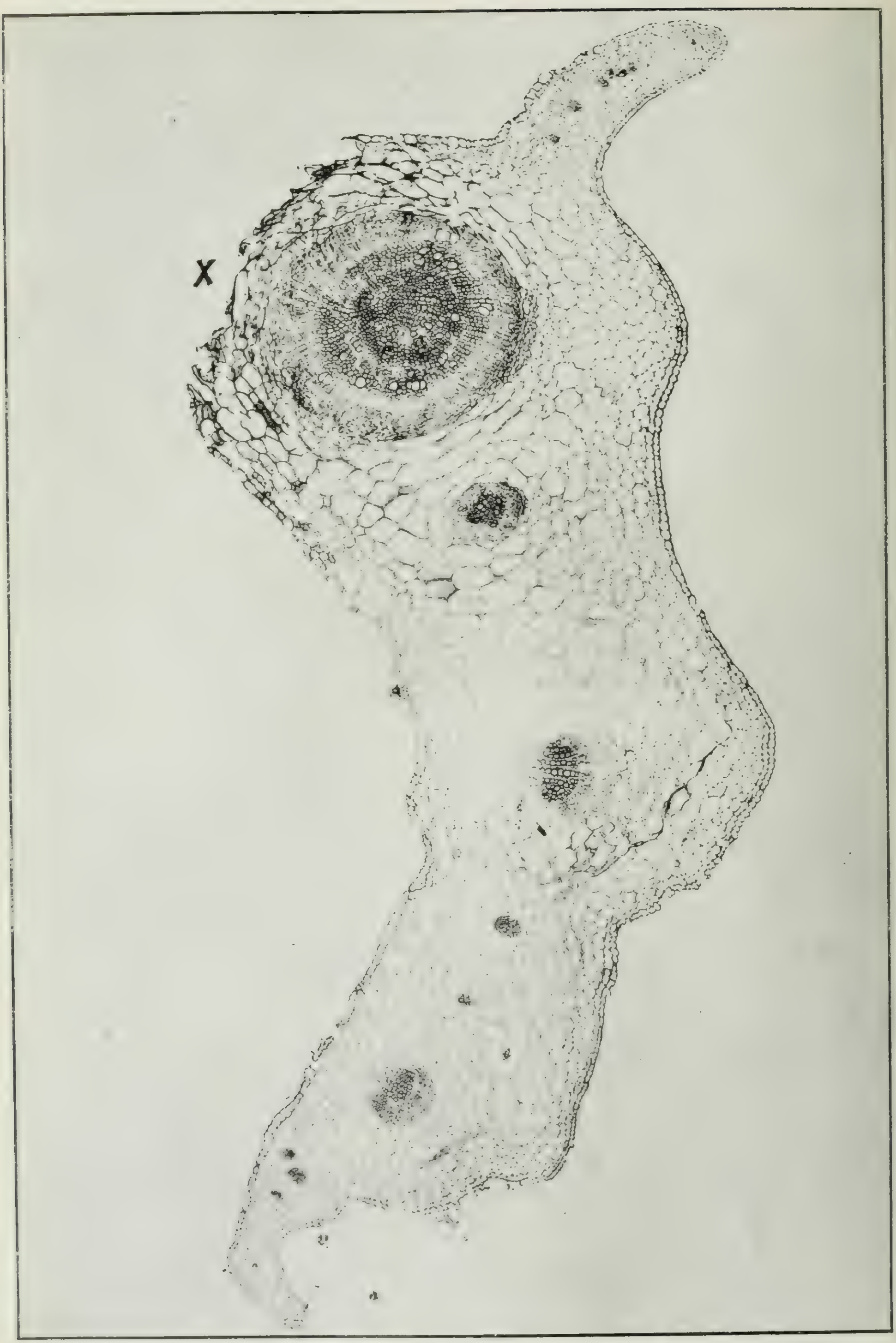
Daisy XIV. Cross section of petiole C, showing abnormal medullary ray with normal and abnormal tracheids (p. 41).



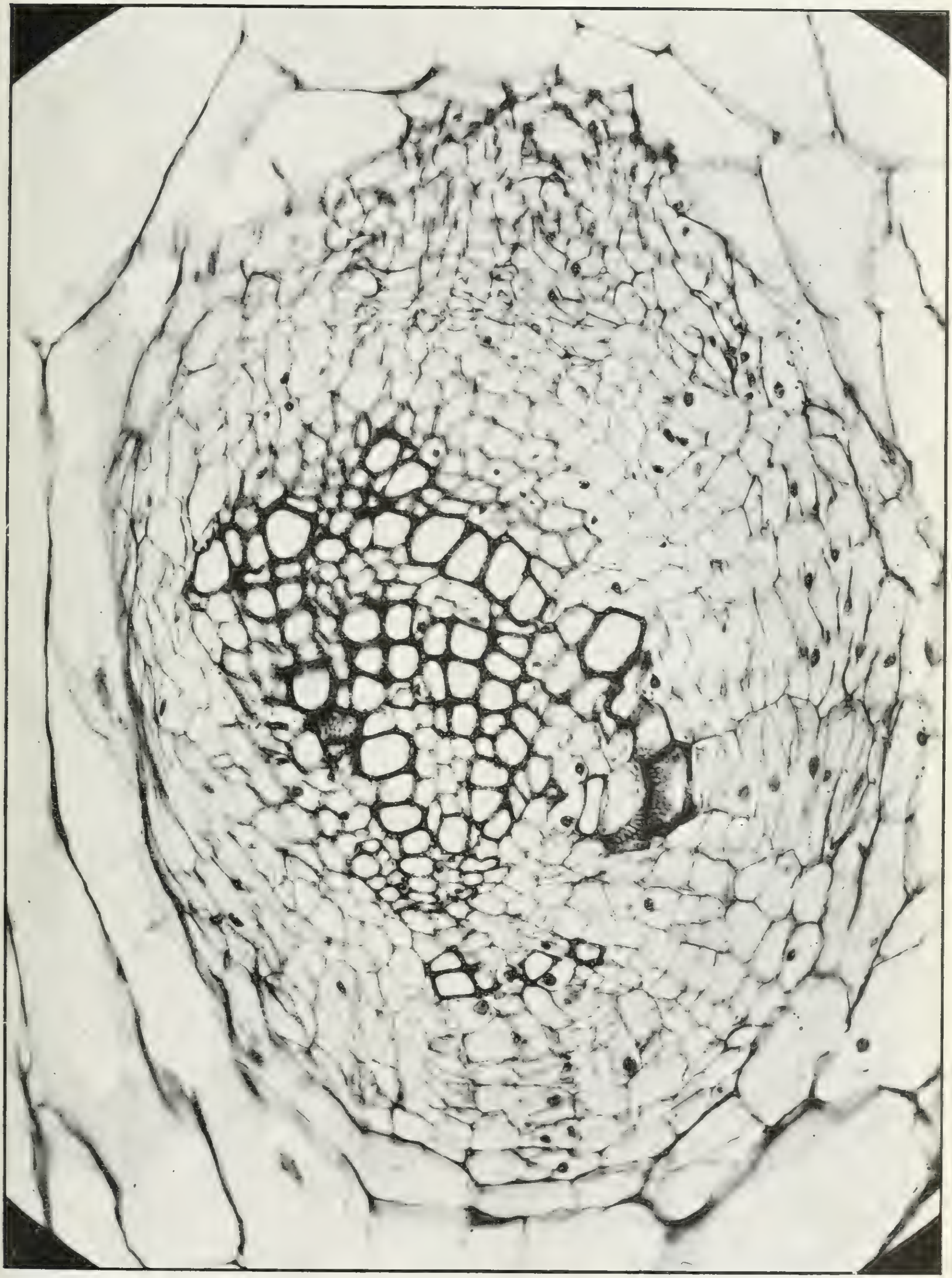
Daisy XIV. Hypertrophied cells in tumor in petiole C (p. 41).



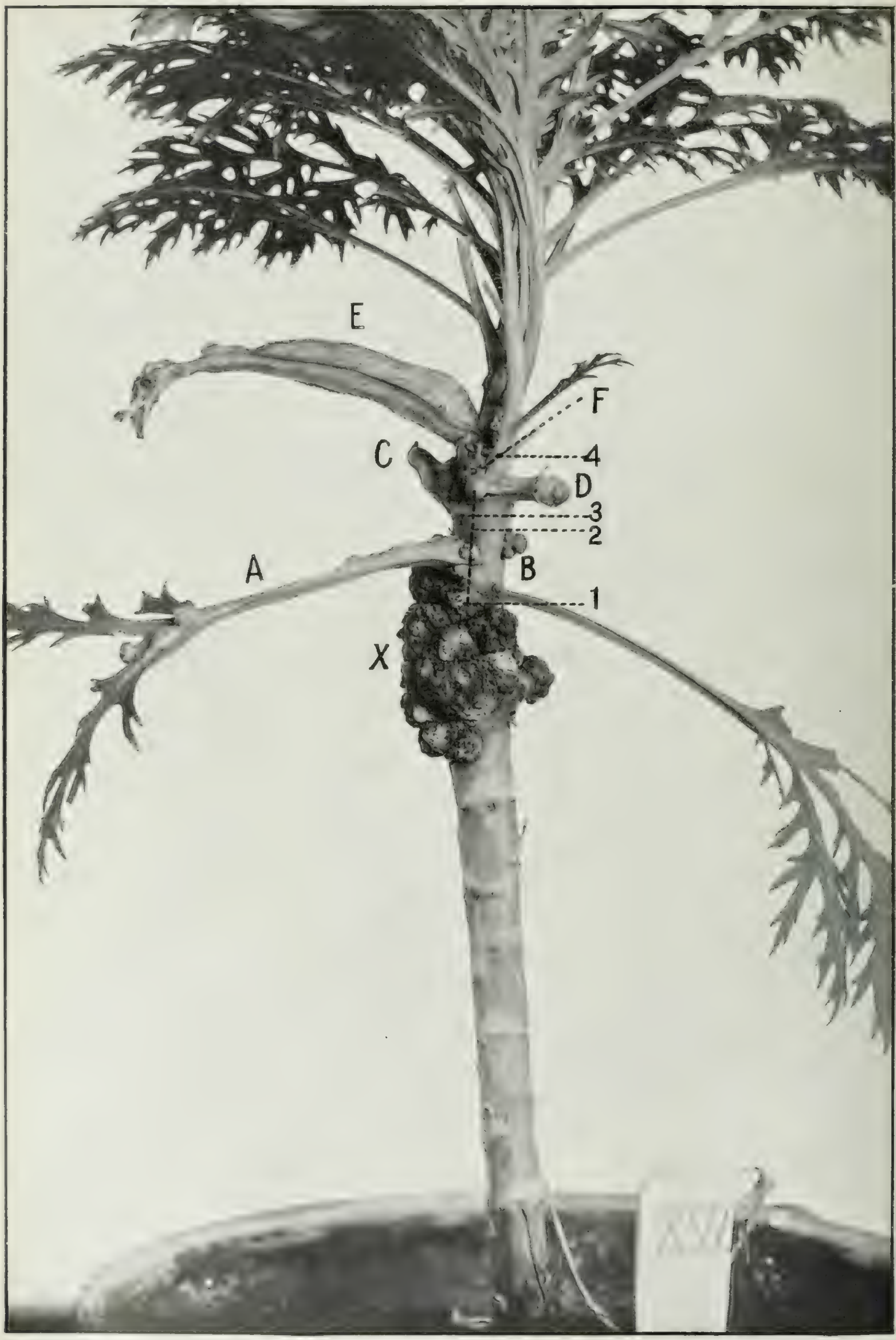
Daisy XIV. Cross section of the tumor-strand in petiole C (p. 41).



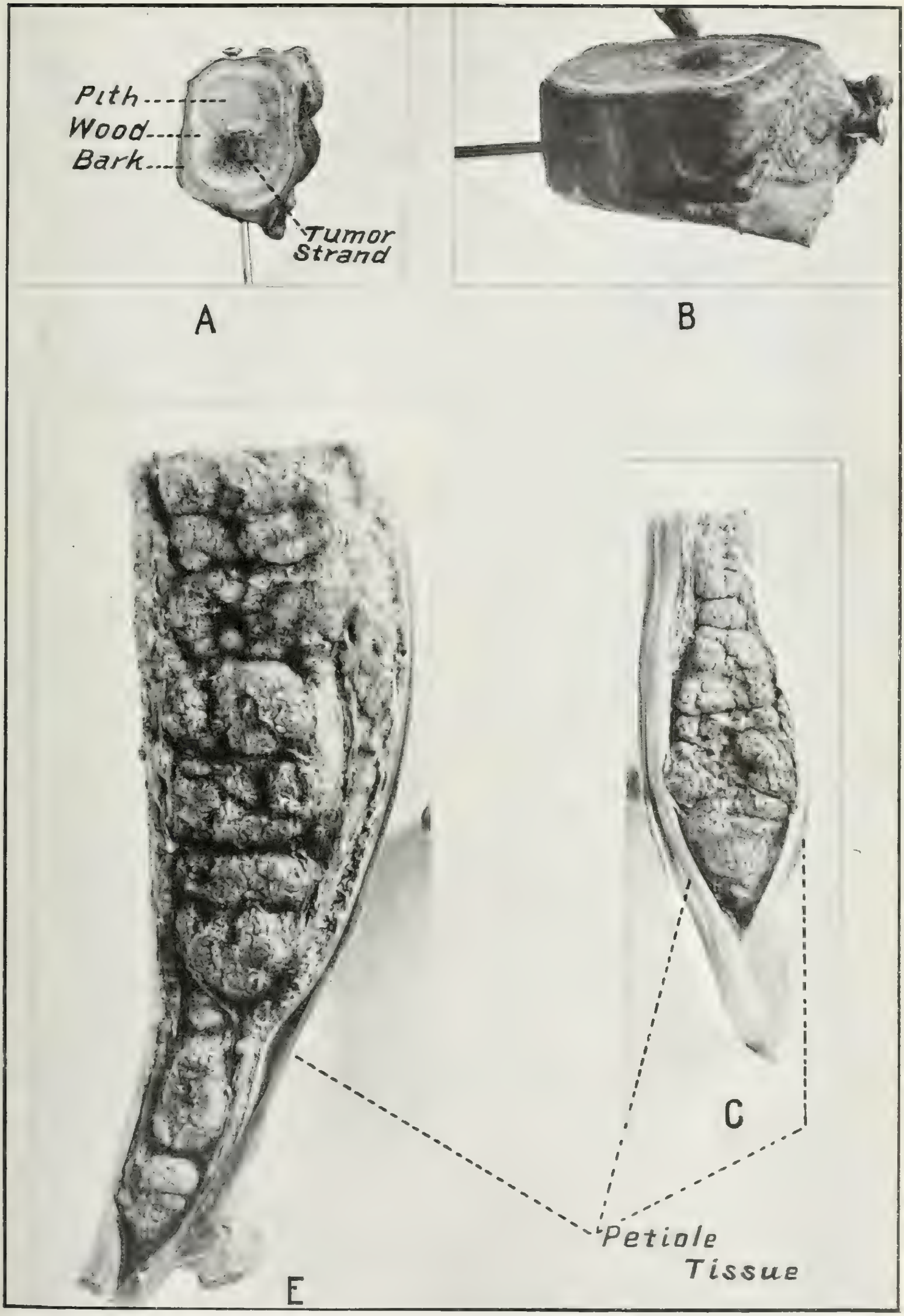
Daisy XIV. Cross section of petiole B, showing a secondary tumor with stem structure at X in a lateral leaf-trace (p. 41).



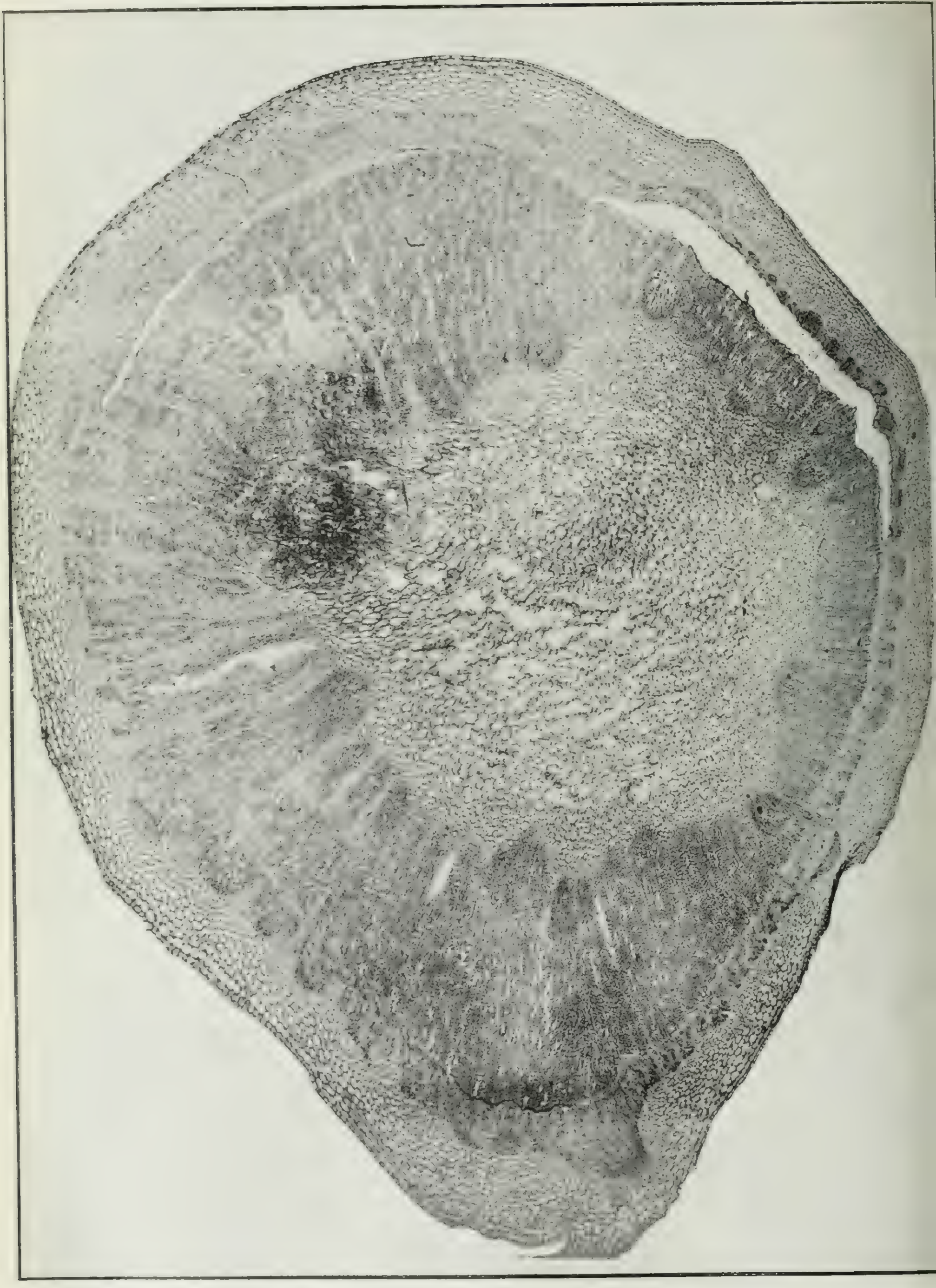
Daisy XIV. Petiole B, showing disturbance in leaf-trace next below X of Plate LIX (p. 42).



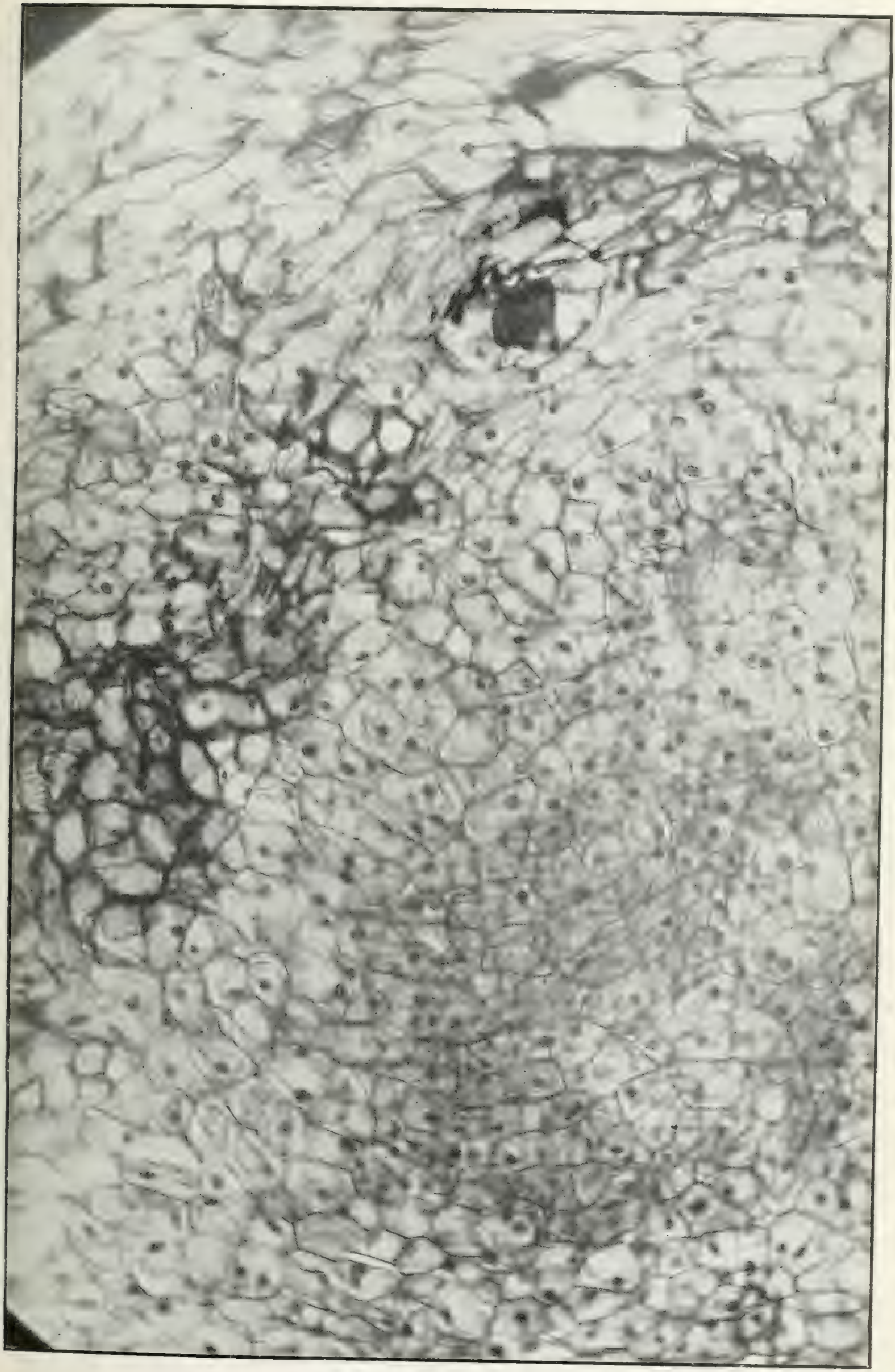
Daisy XVI. Inoculated plant, showing primary stem tumor and secondary leaf tumors (p. 42).


Pith
Wood
Bark
Tumor Strand
A
B
Petiole Tissue
C
E

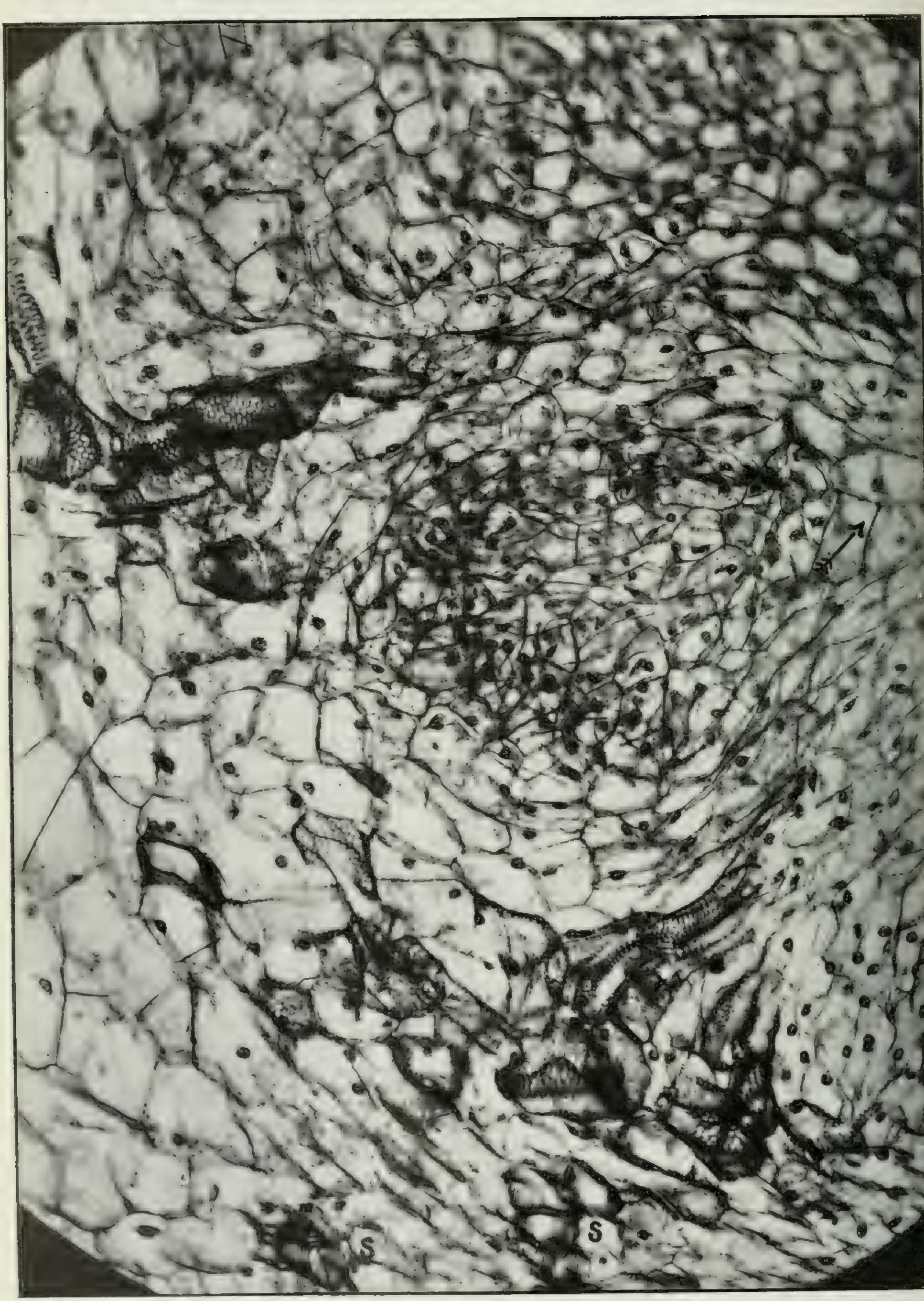
Daisy XVI. Cross section of stem between tumors, showing protrusion of tumor-strand; also petioles enlarged to show how the secondary tumor reaches the surface, i. e., by splitting open the overlying tissues (p. 42).



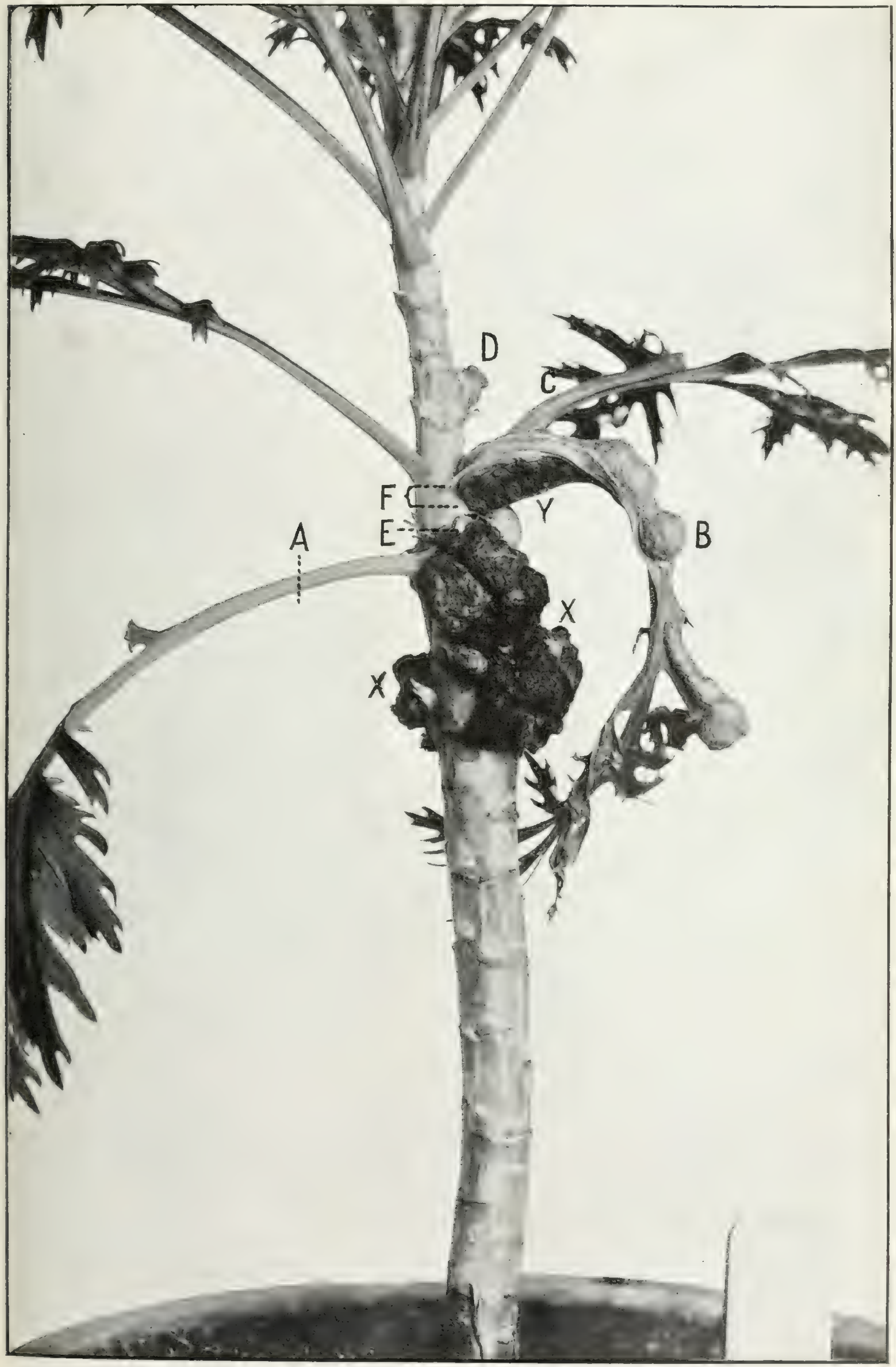
Daisy XVI. Magnified cross-section of stem between tumors; tumor-strand at left; wood cylinder thickened in three-fourths of its circumference (p. 43).



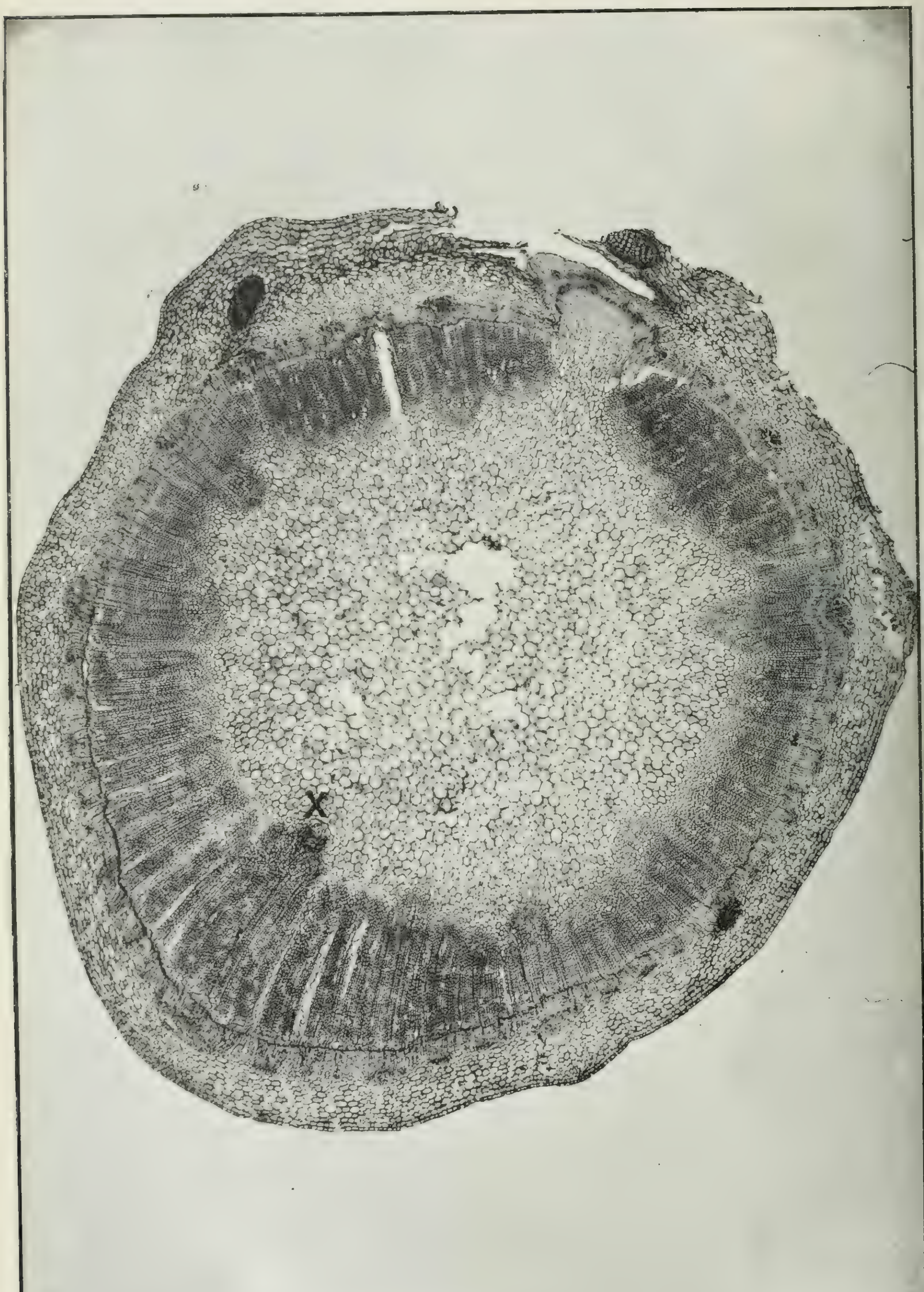
Daisy XVI. Margin of small portion of tumor-strand from Plate LXIII (p. 43).



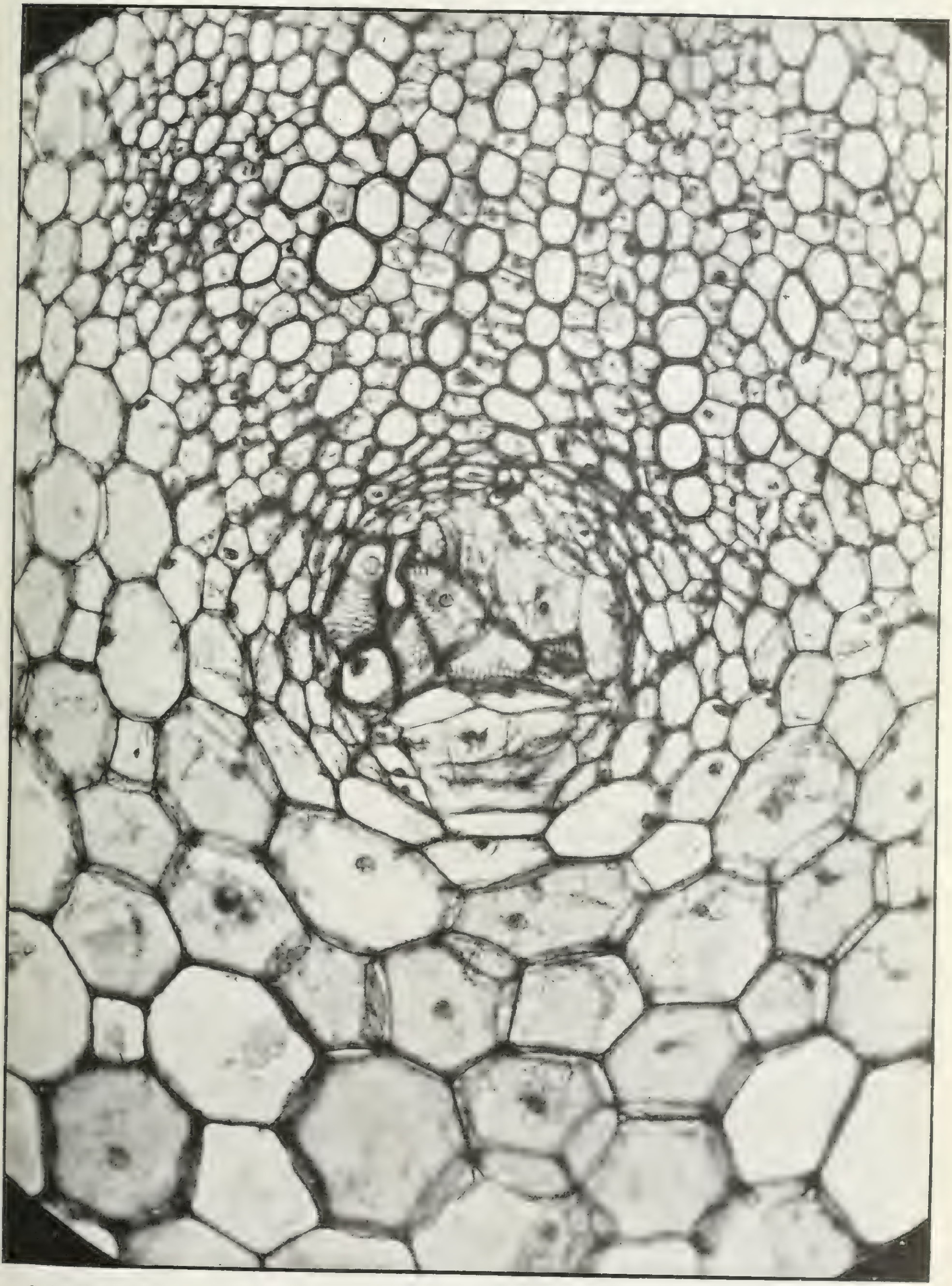
Daisy XVI. Tumor-strand and stream of twisted tracheids, spirals at S, with remainder of them in direction of the arrow (p. 43).



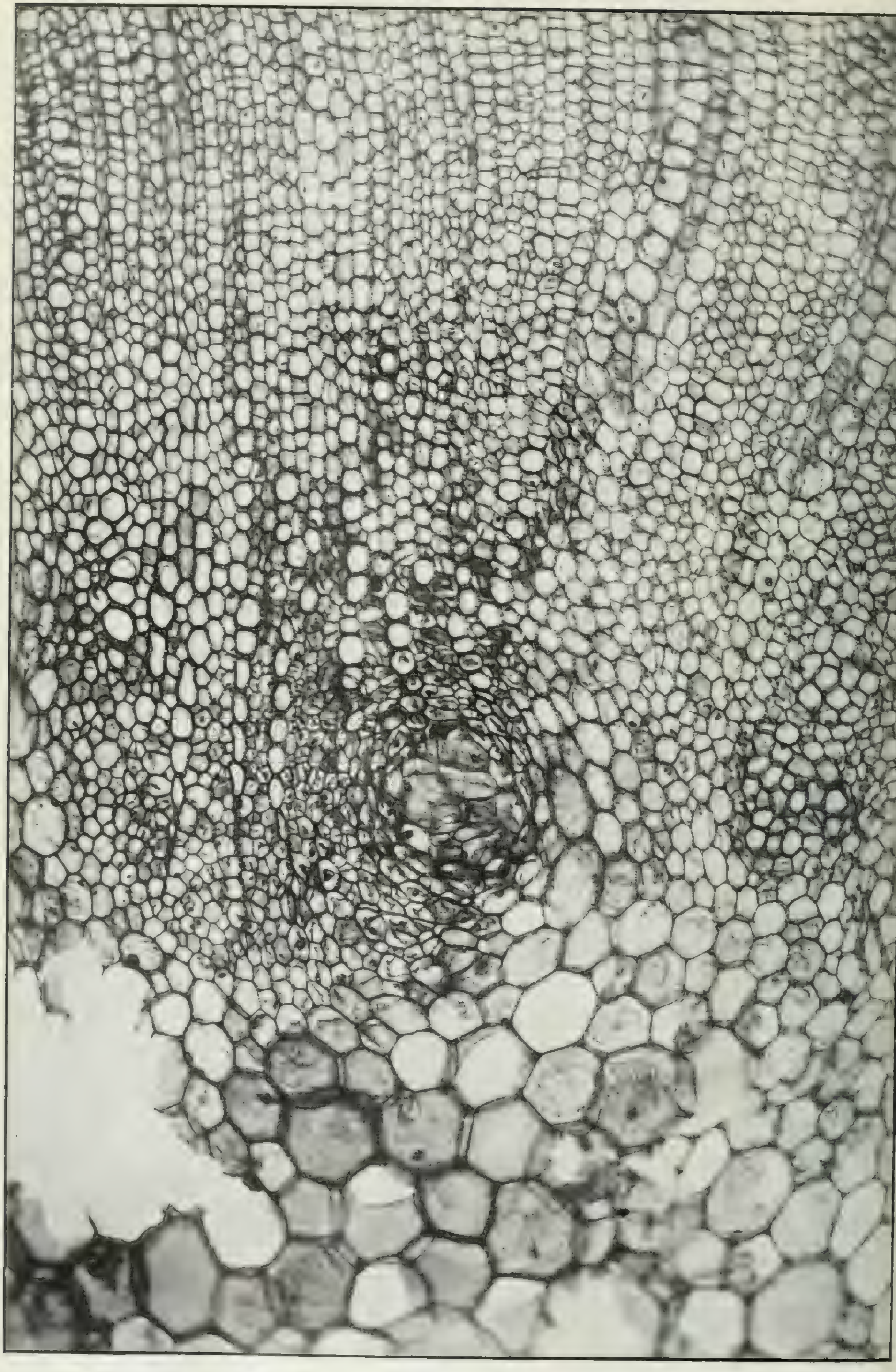
Daisy XVII. Inoculated plant, showing primary stem tumor and secondary leaf tumors (p. 43).



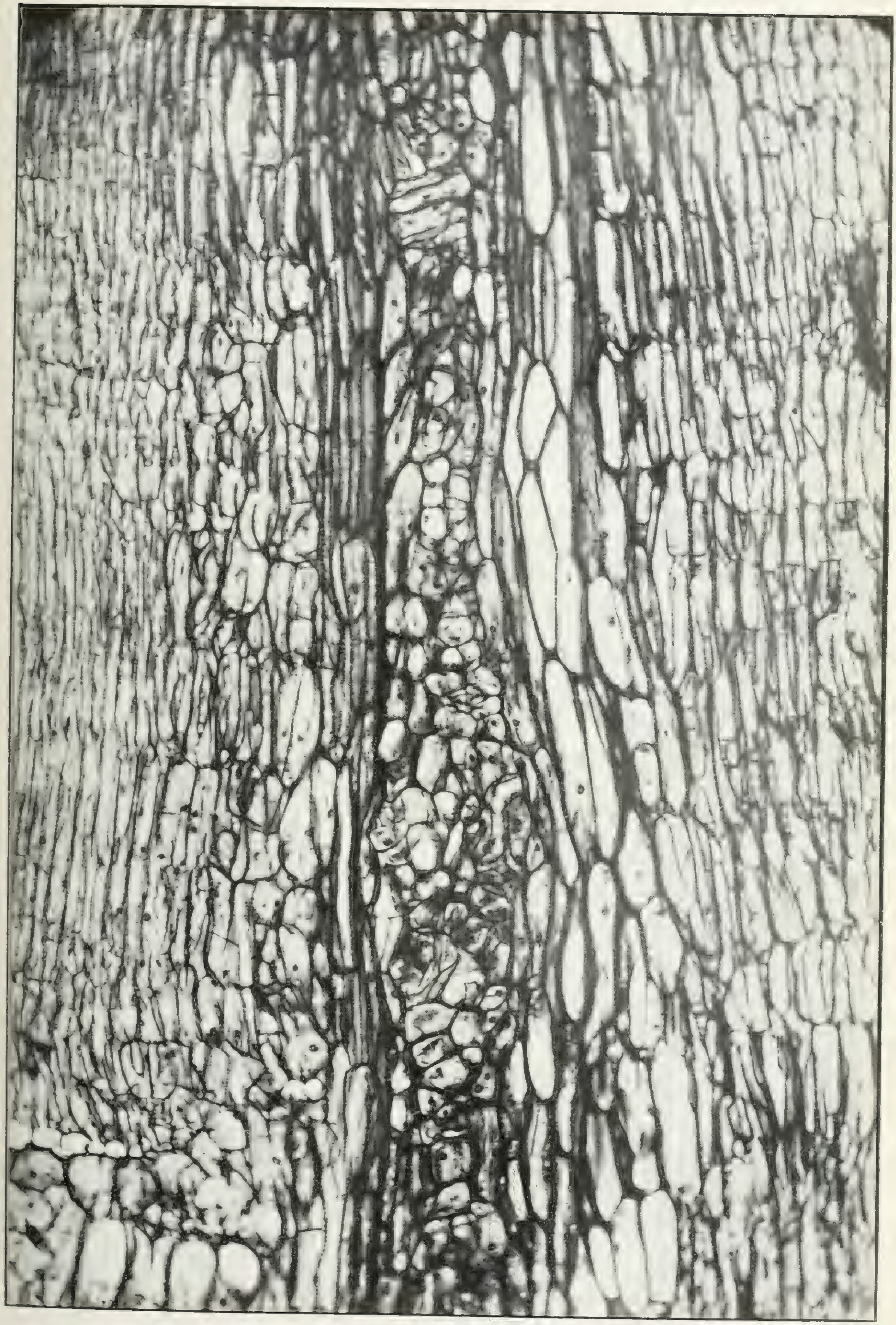
Daisy XVII. Cross section of stem between tumors, showing a small tumor-strand at X (p. 44).



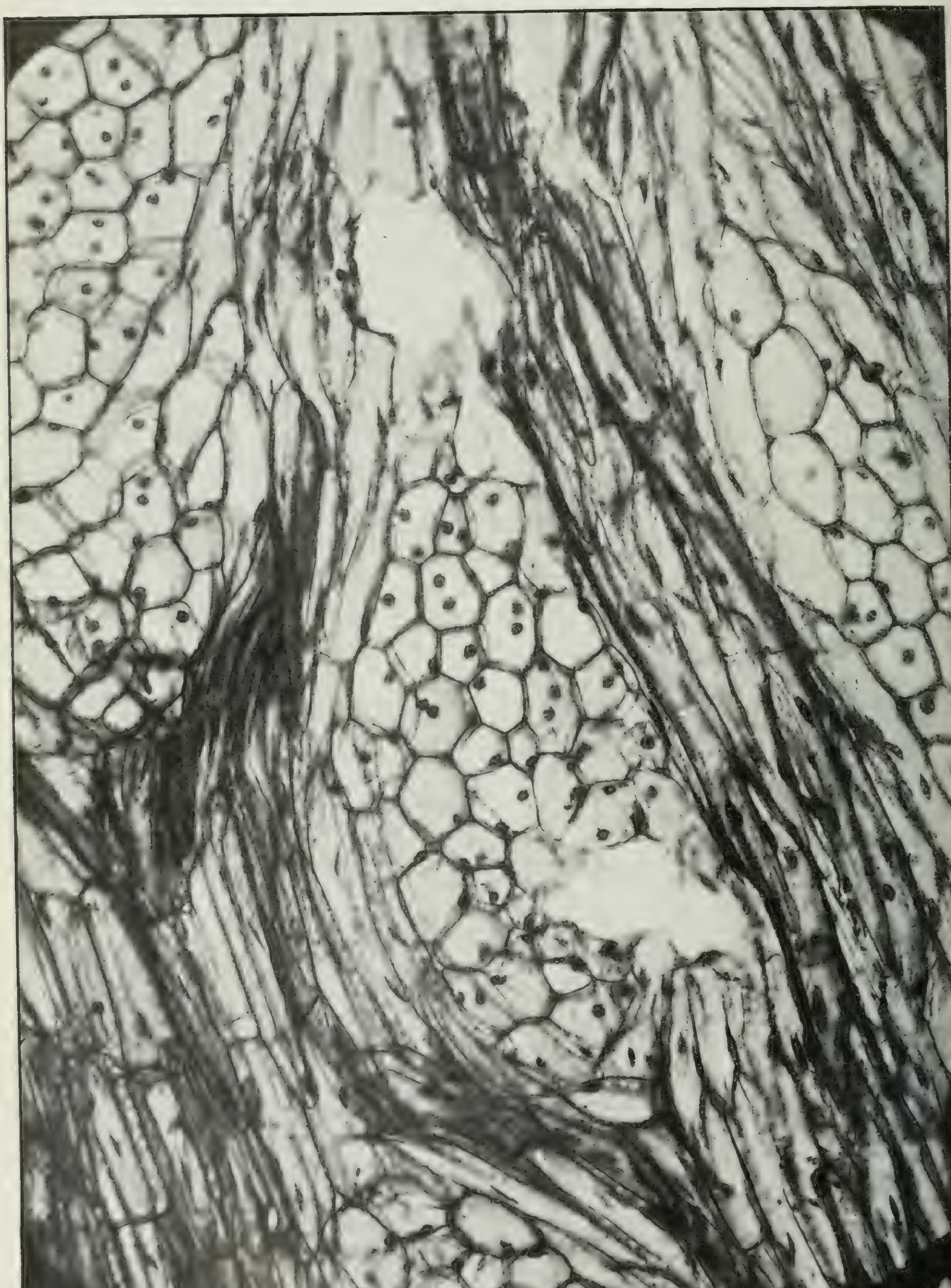
Daisy XVII. Portion of Plate LXVII enlarged, showing tracheids developed in the tumor-strand; the vessels immediately above are spirals (p. 44).



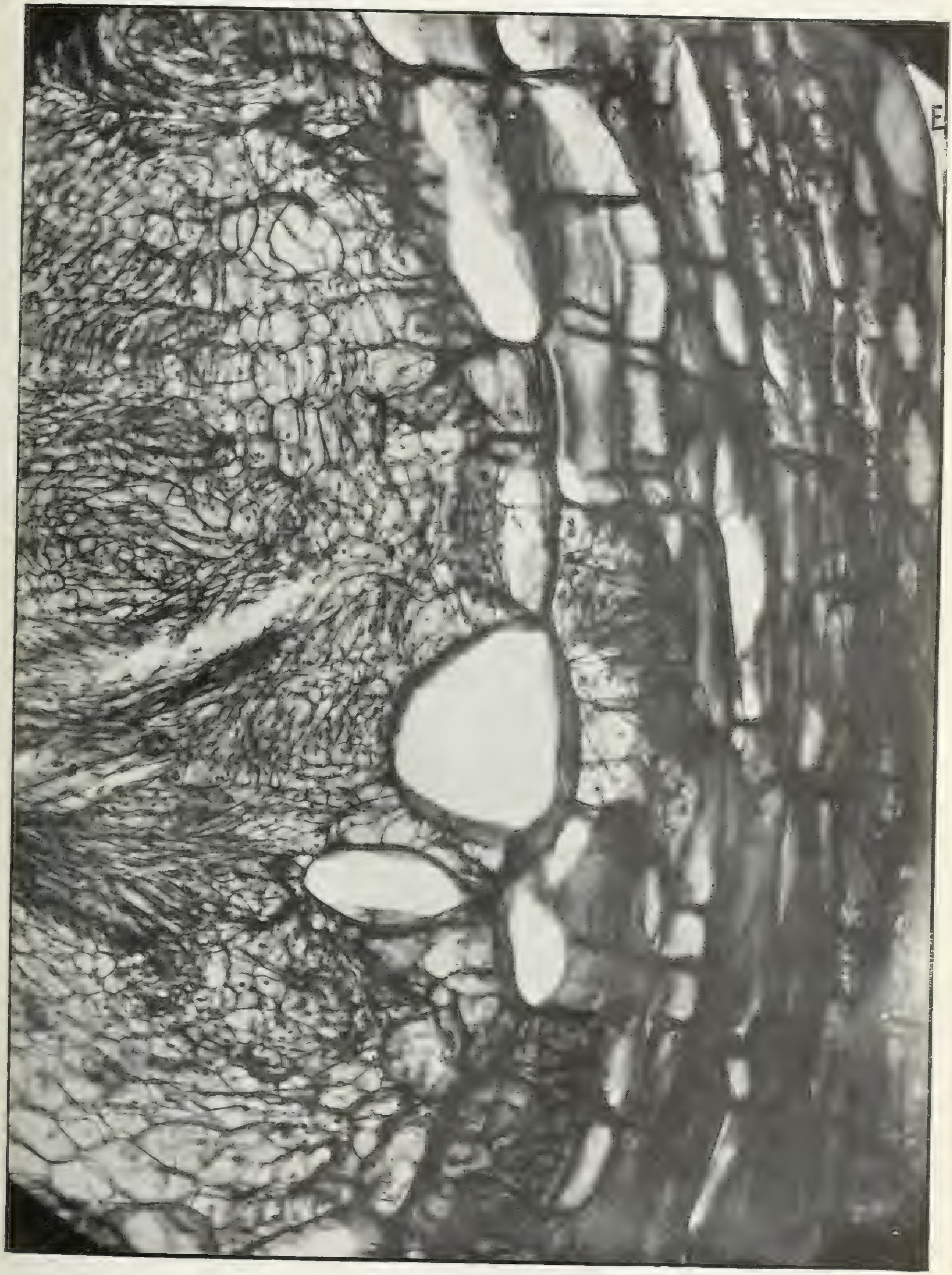
Daisy XVII. Cross section of stem at another level, showing tumor-strand (p. 44)



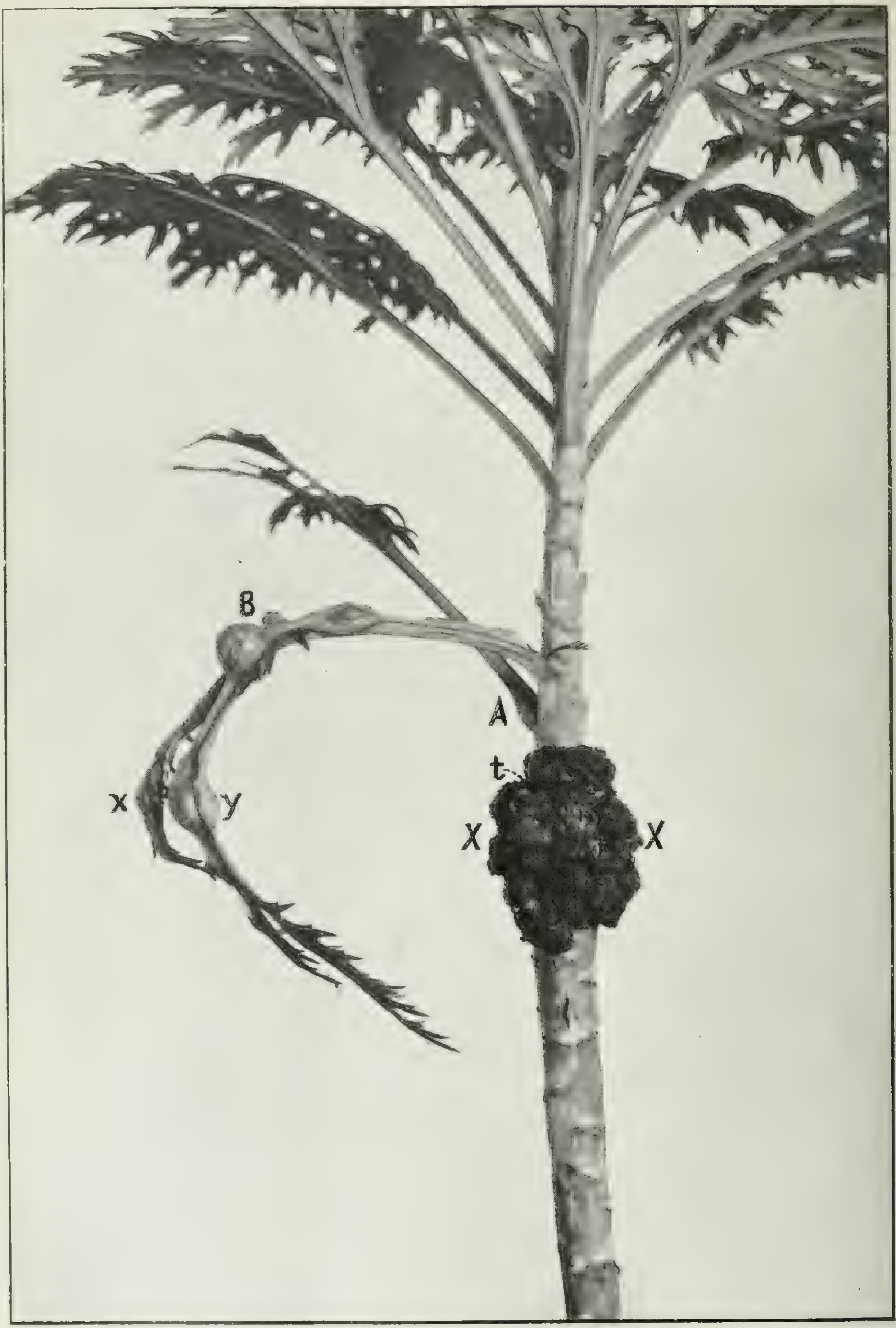
Daisy XVII. Longitudinal section of petiole C, showing tumor-strand (p. 44).



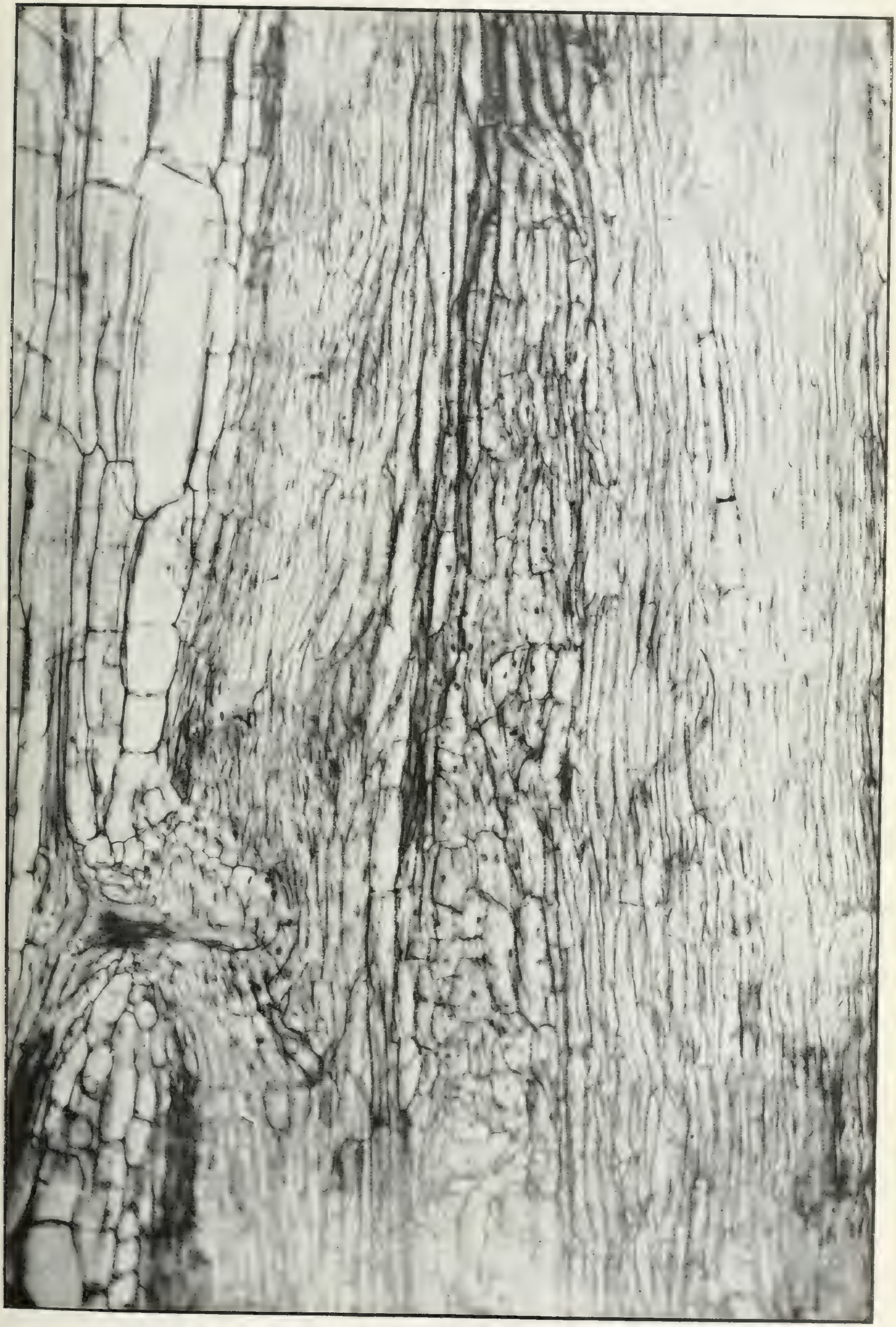
Daisy XVII. Tumor tissue of petiole C with bi- and tri-nucleate cells (p. 45).



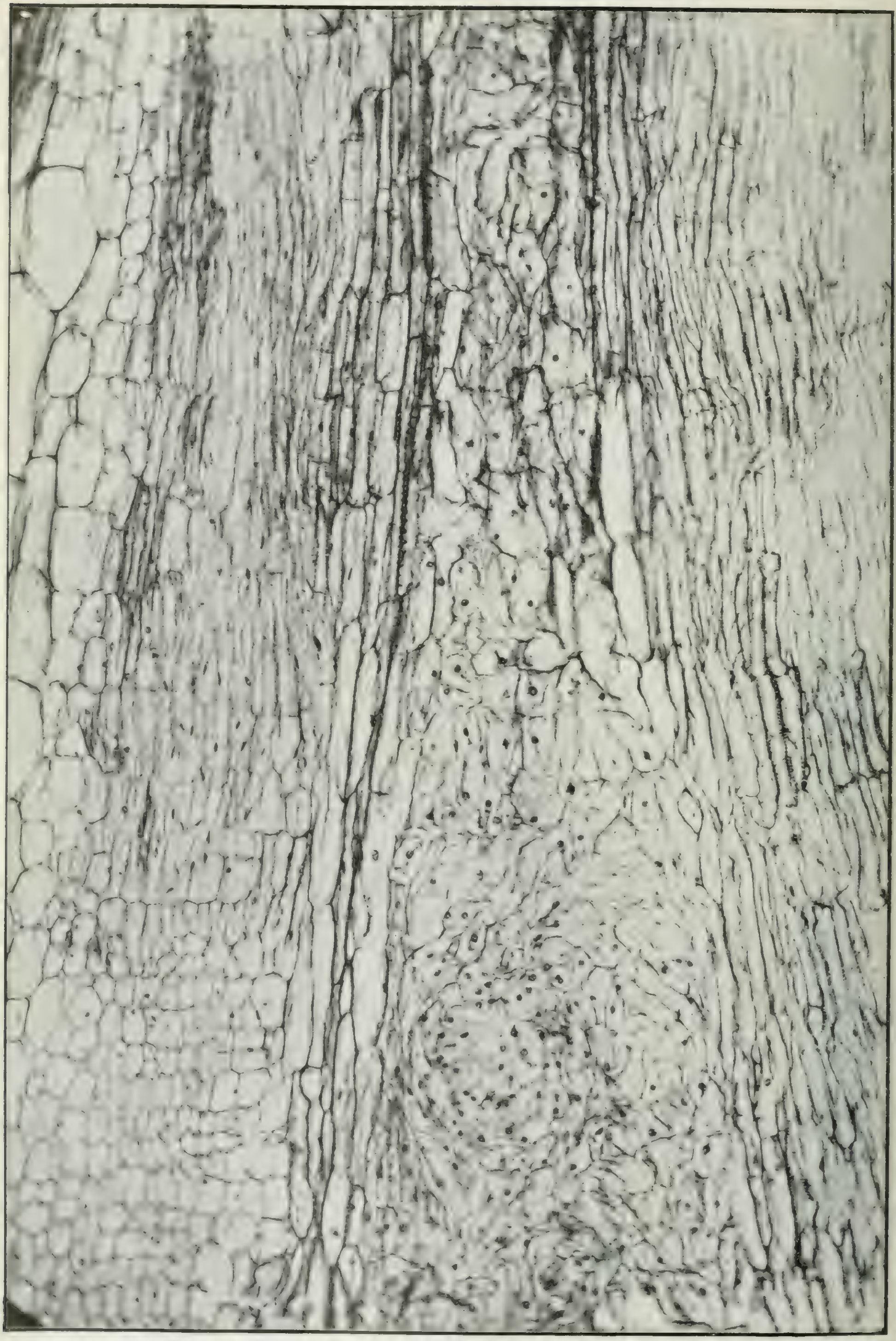
Daisy XVII. Margin of secondary tumor (petiole C) showing infiltration (p. 45).



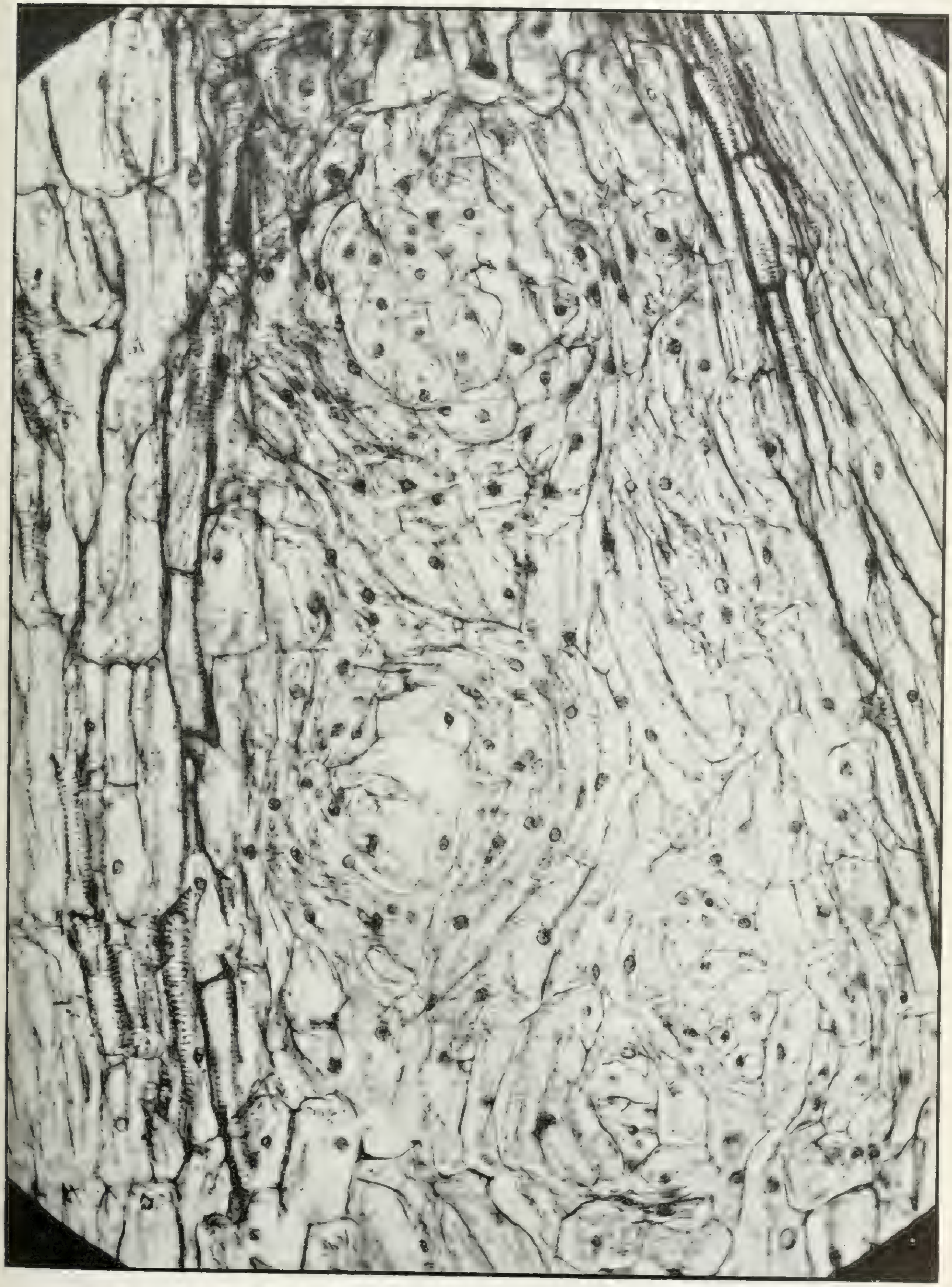
Daisy XVIII. Inoculated plant, showing primary tumor on stem and secondary tumors on leaves (p. 45).



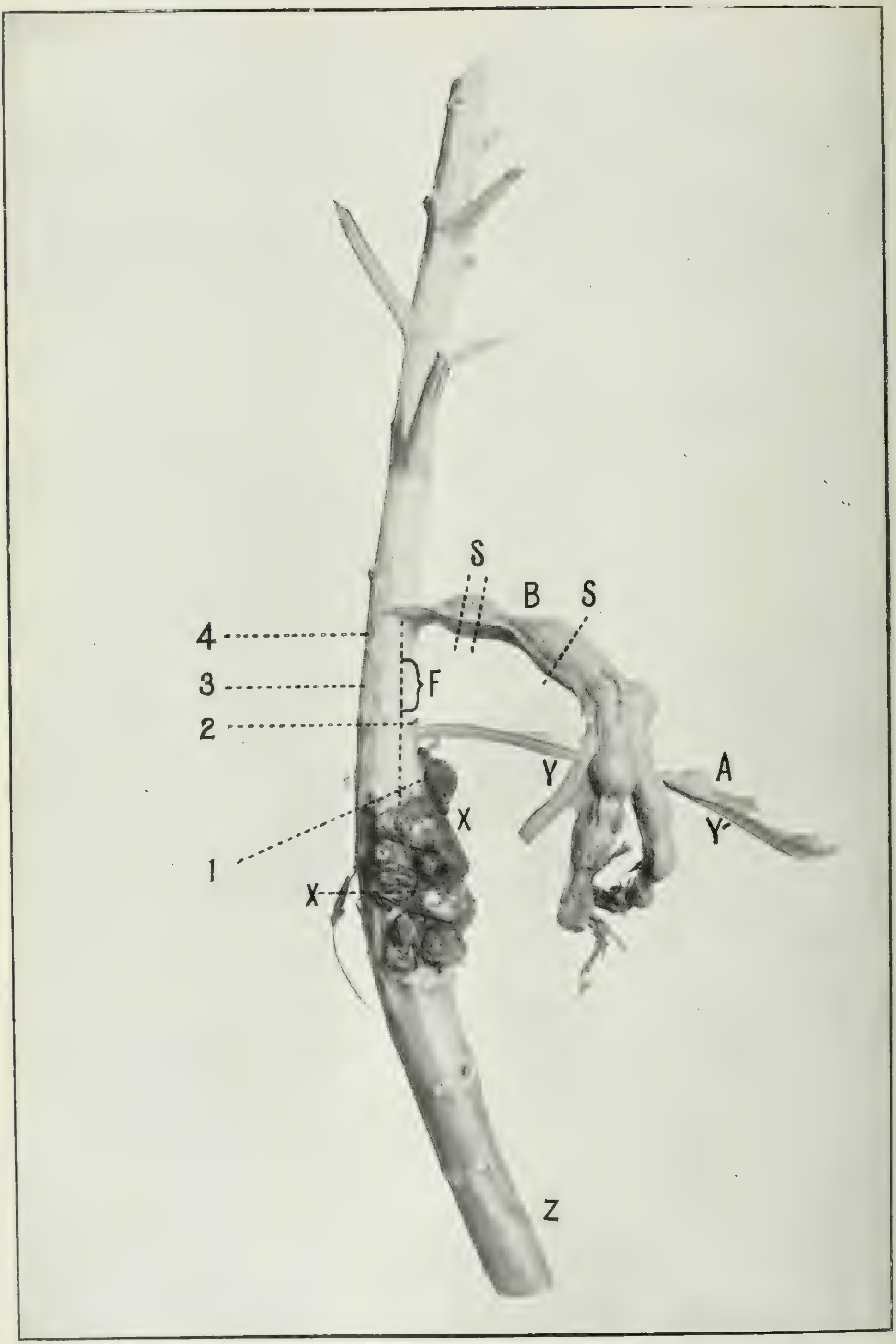
Daisy XVIII. Longitudinal section of petiole A, showing tumor-strand (p. 45).



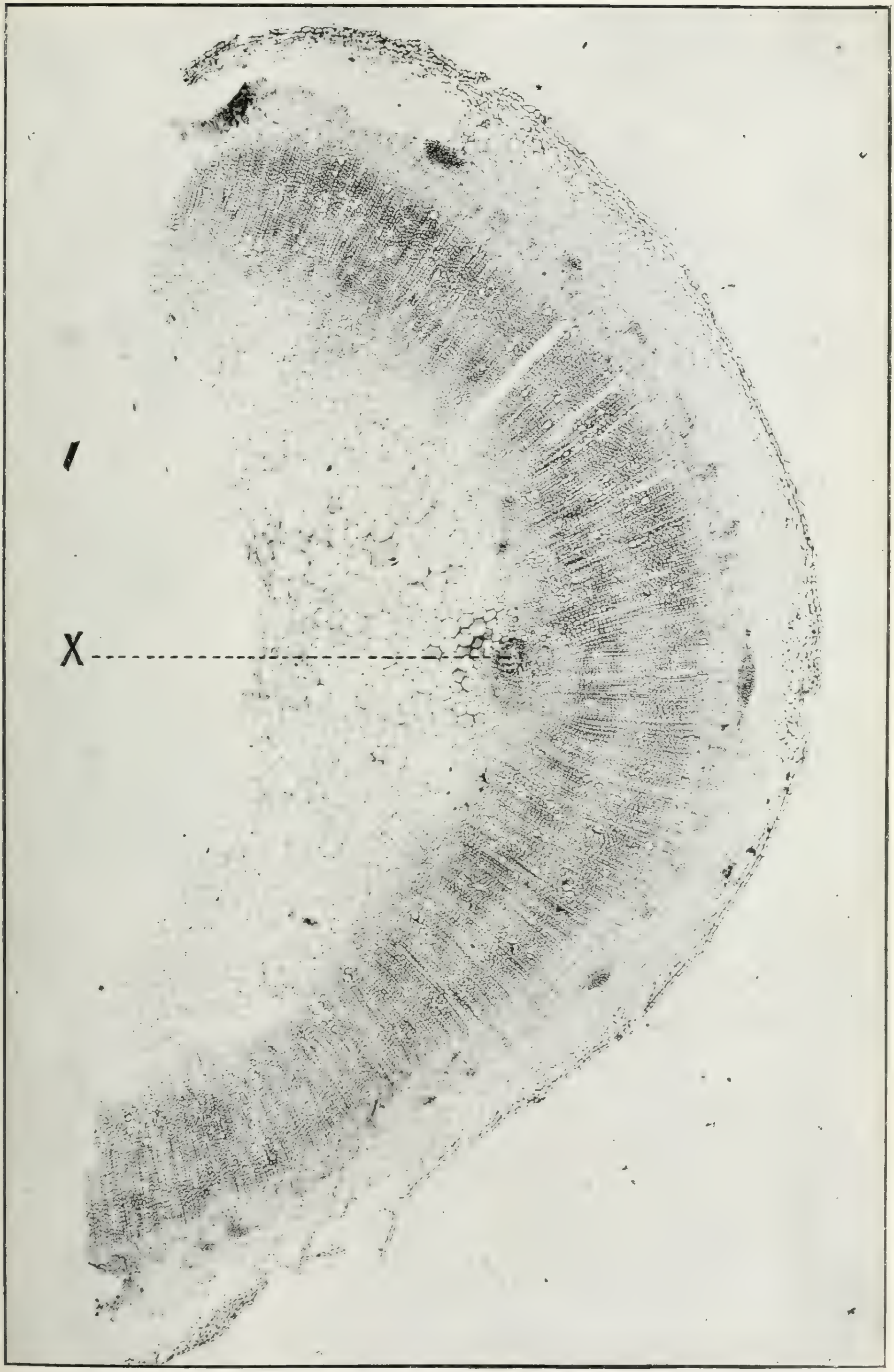
Daisy XVIII. Tumor-strand in petiole A; joins on to Plate LXXIV (p. 46).



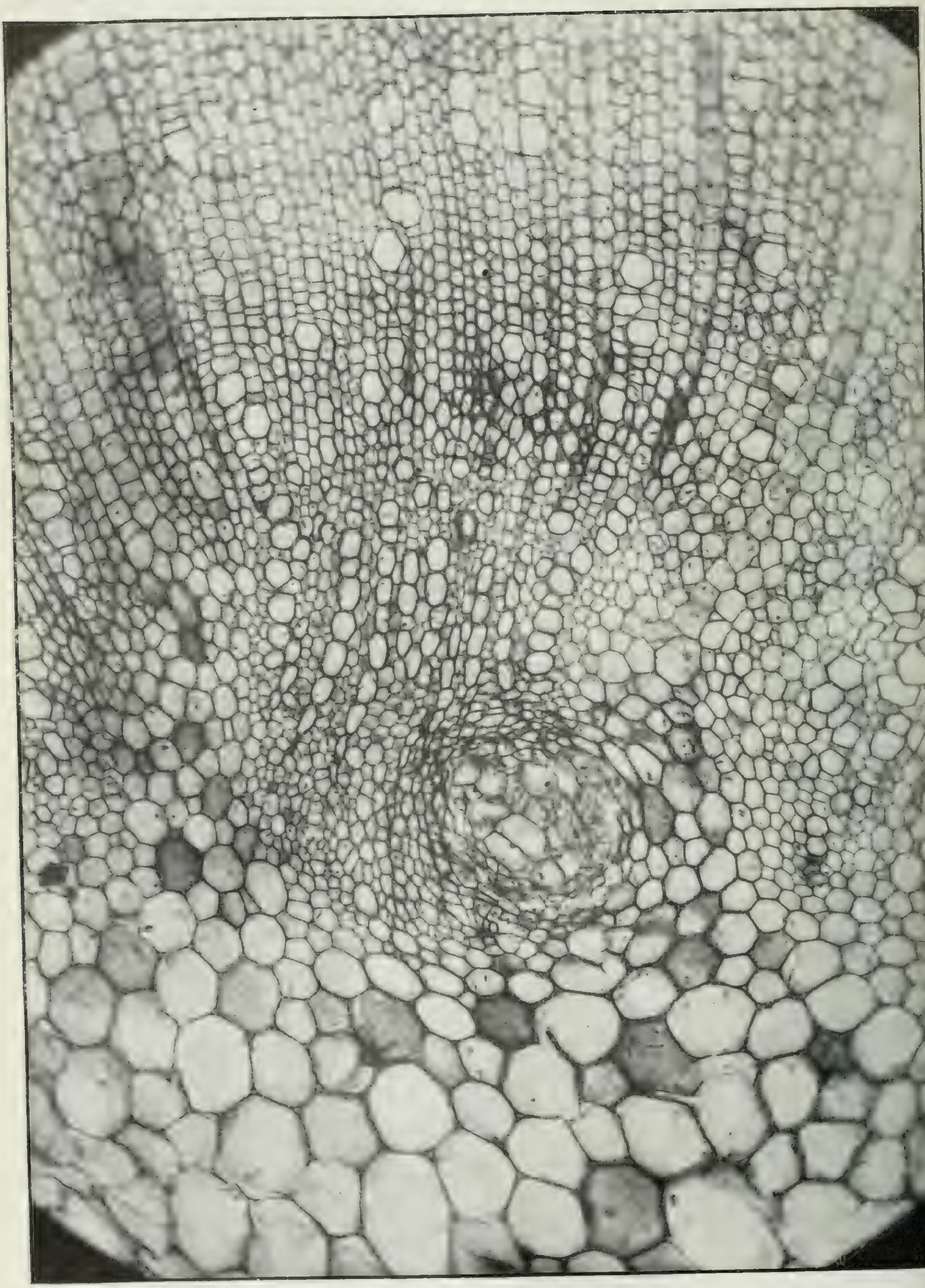
Daisy XVIII. Tumor-strand in petiole A; joins on to Plate LXXV (p. 46).



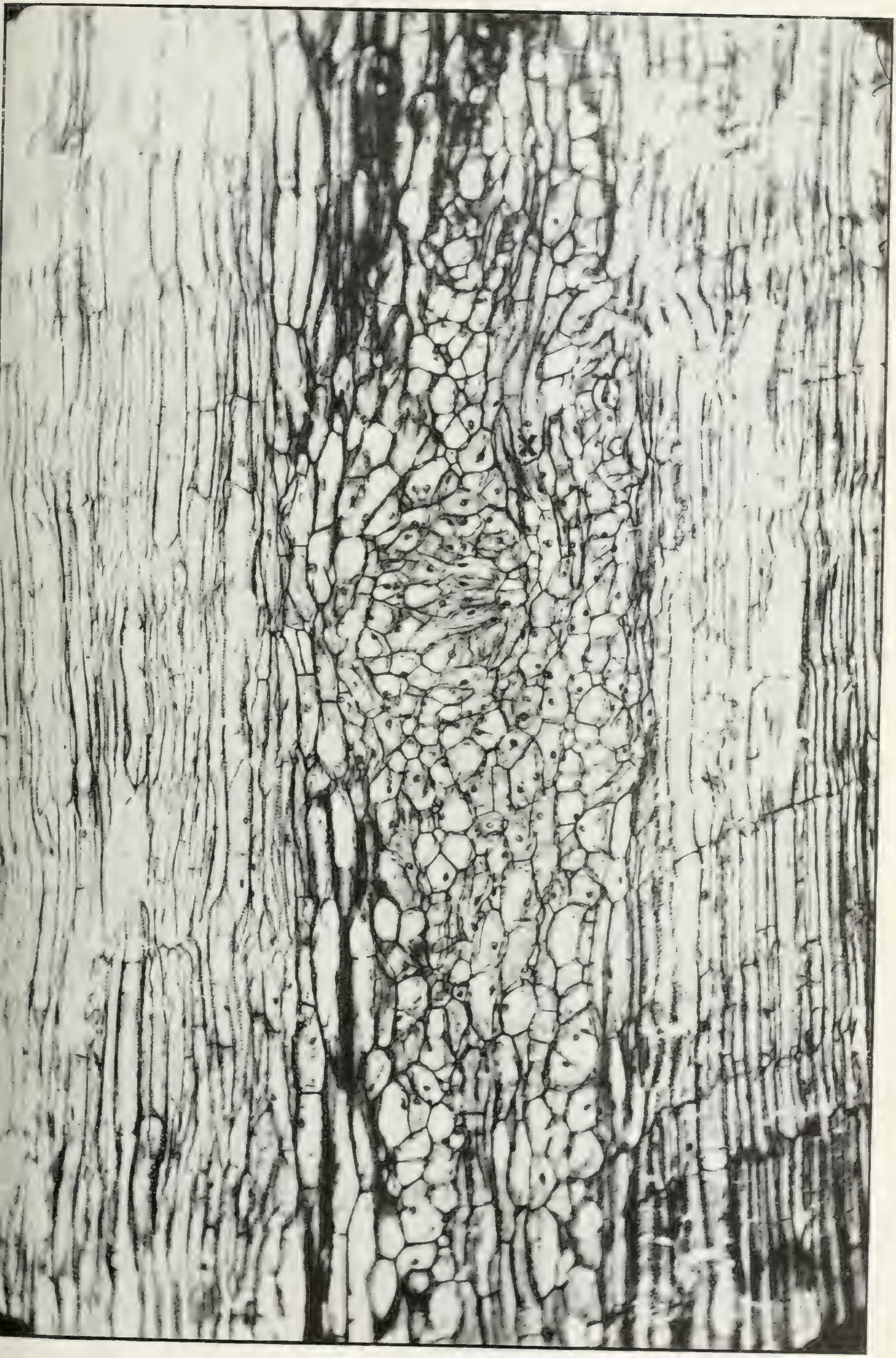
Daisy XIX. Portion of inoculated plant, showing primary stem tumor and secondary leaf tumors (p. 46).



Daisy XIX. Cross section of stem between tumors, showing a tumor-strand at X (p. 46).

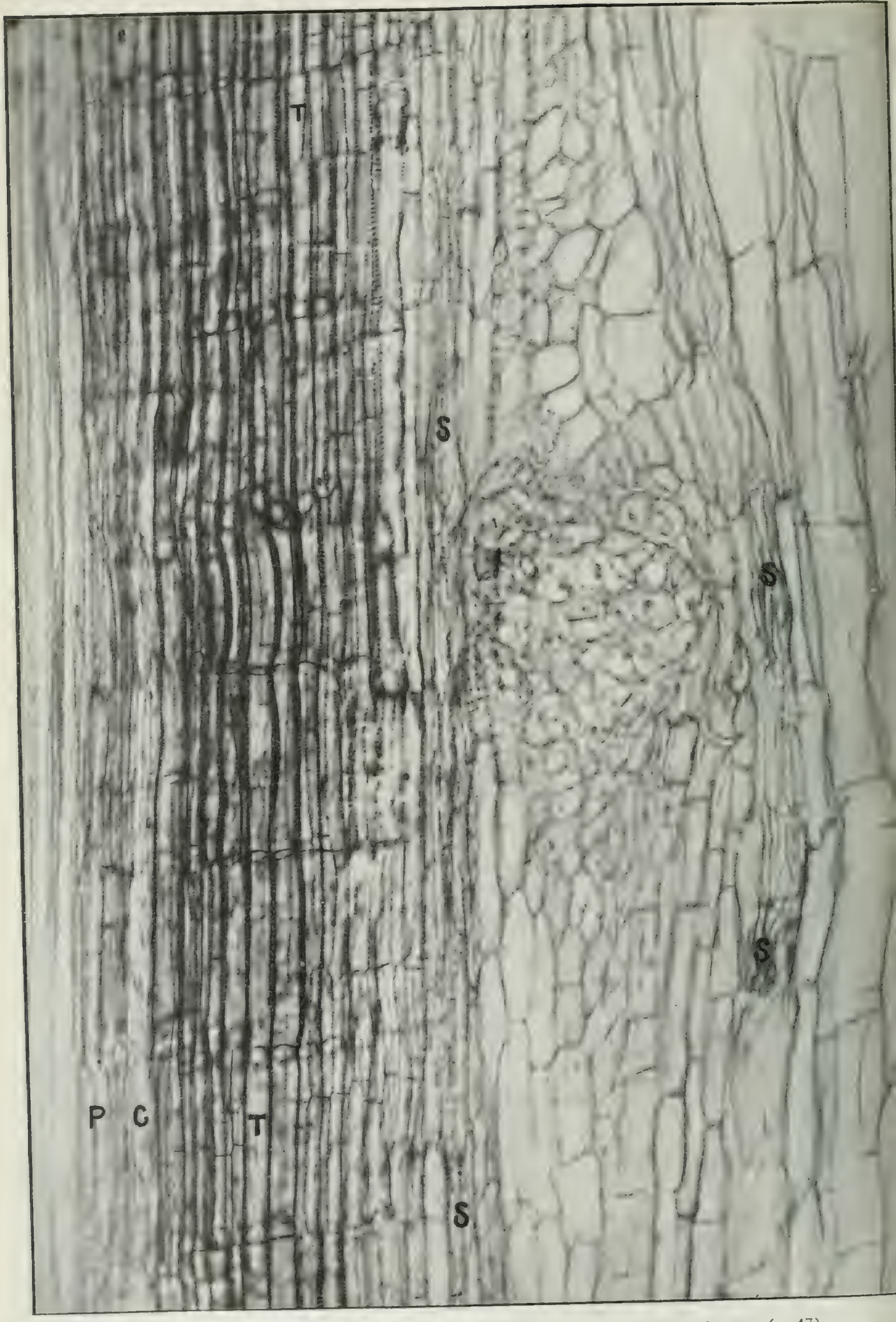


Daisy XIX. A part of Plate LXXVIII, showing tumor-strand region in detail; wood above, pith below (p. 46).

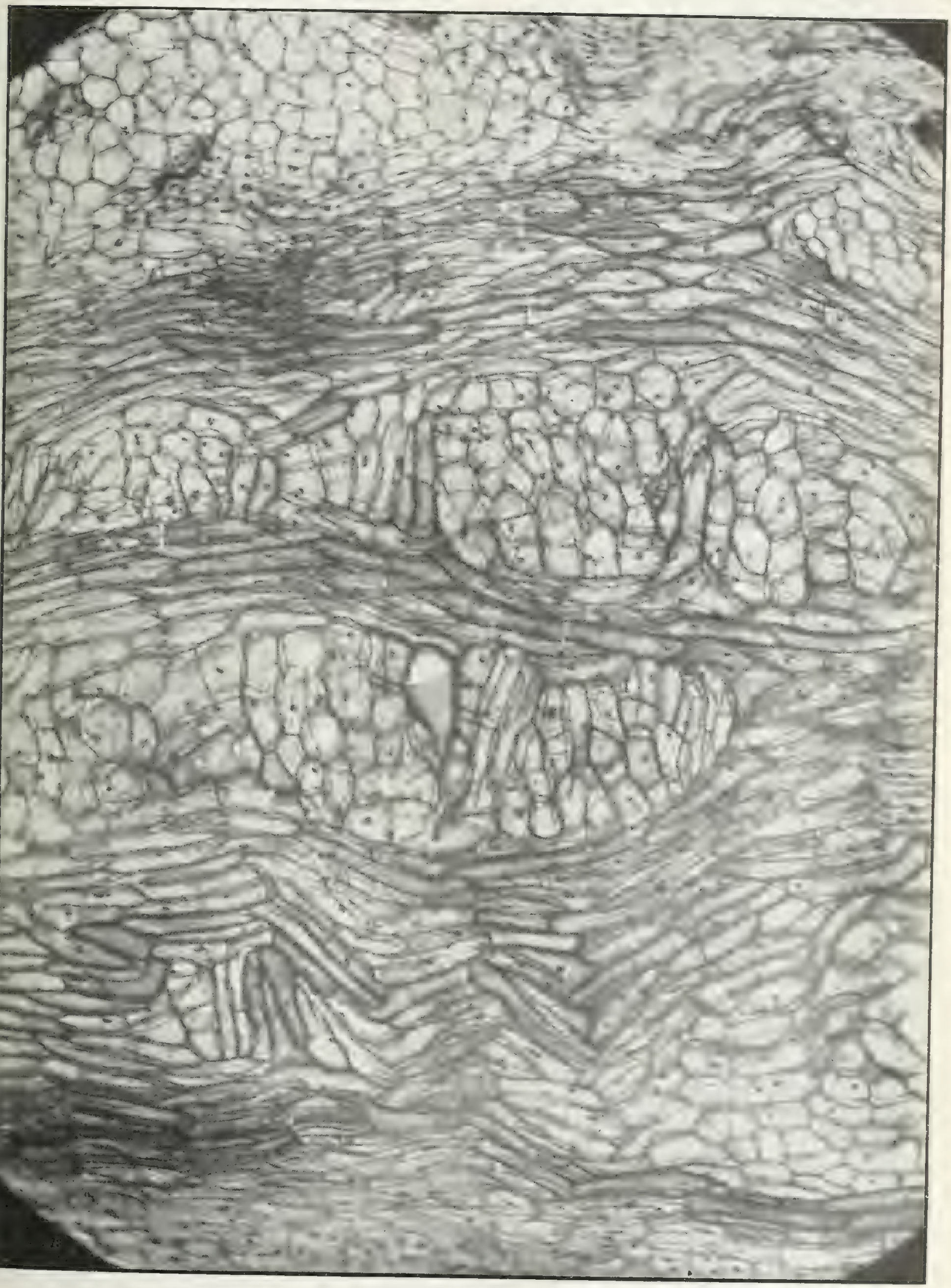


Daisy XIX. Longitudinal section of base of petiole A, showing tumor-strand (p. 47).

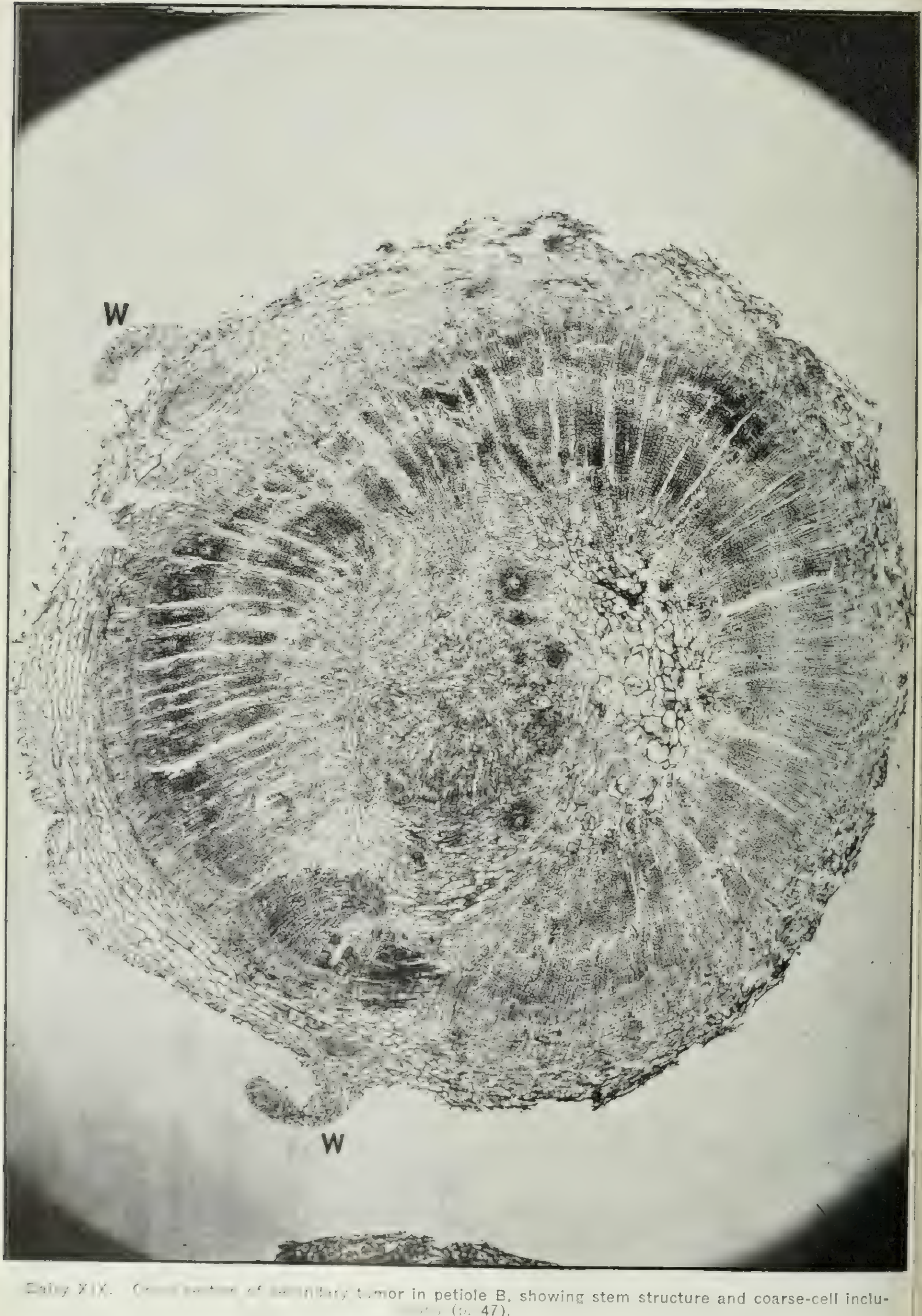
PLATE LXXXI.



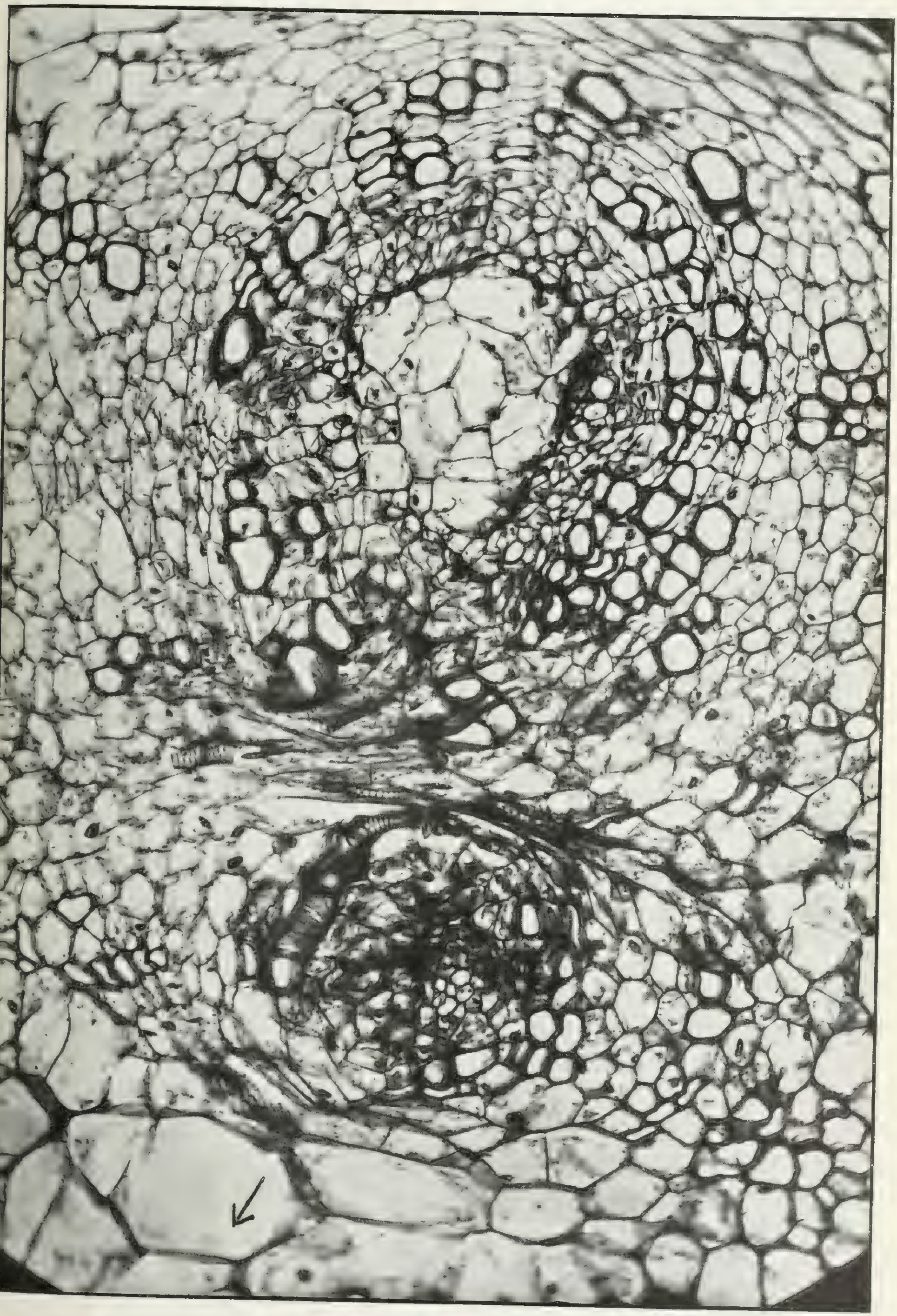
Daisy XIX. Longitudinal section of middle part of petiole A, between tumors (p. 47).



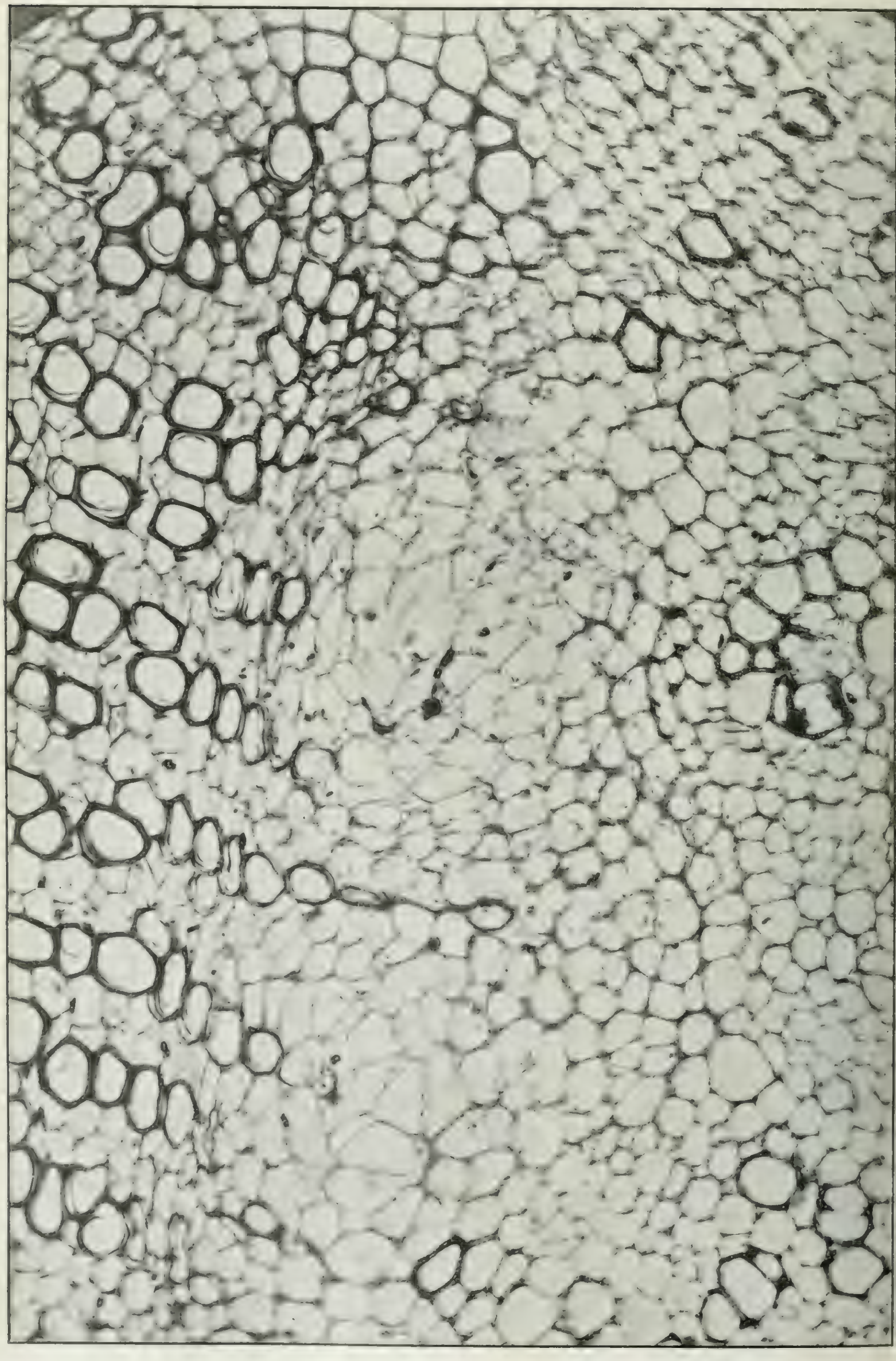
Daisy XIX. Tumor at Y on petiole A, showing the supporting stroma of tracheids (p. 47).



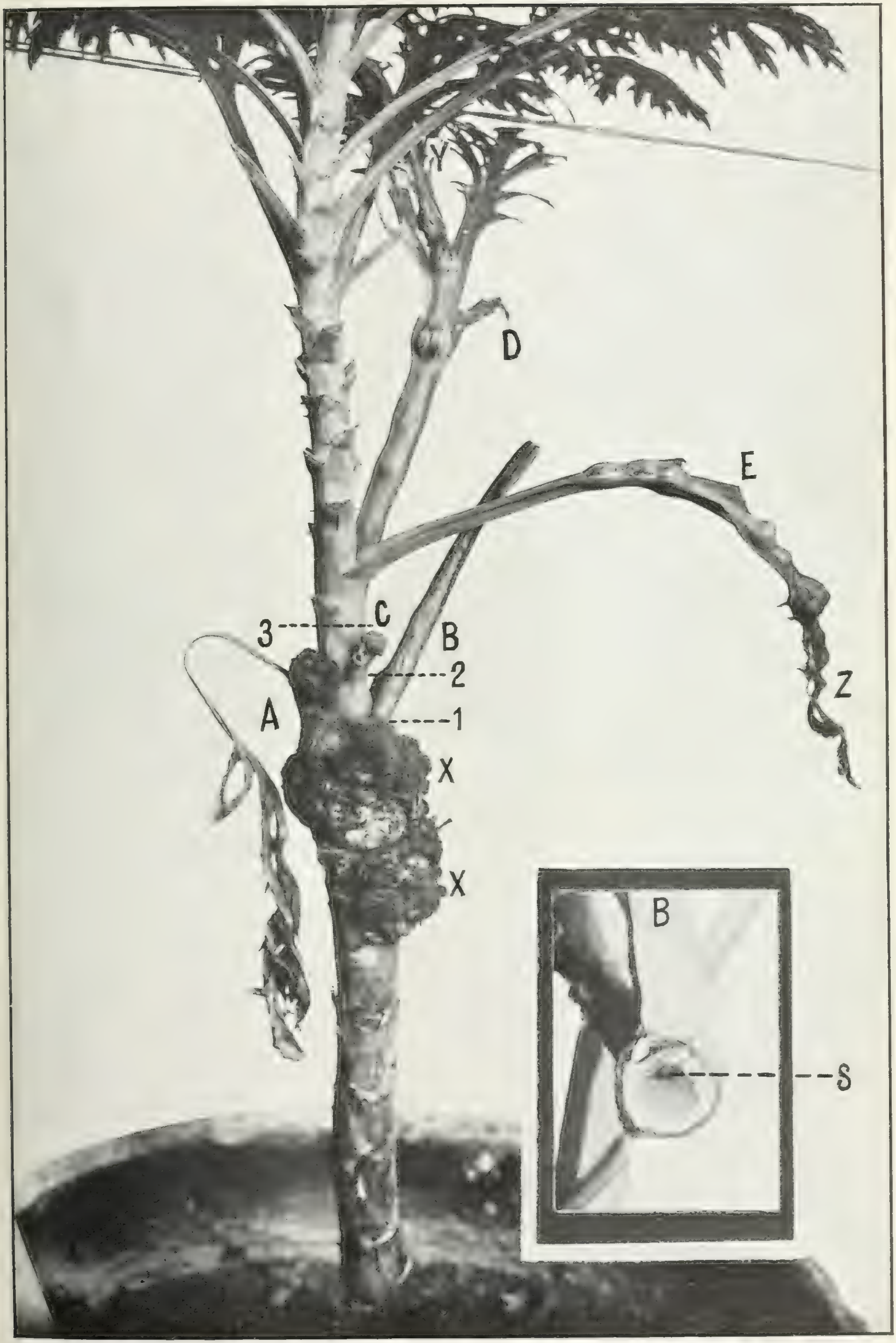
Daisy XIX. Cross section of secondary tumor in petiole B, showing stem structure and coarse-cell inclusions (p. 47).



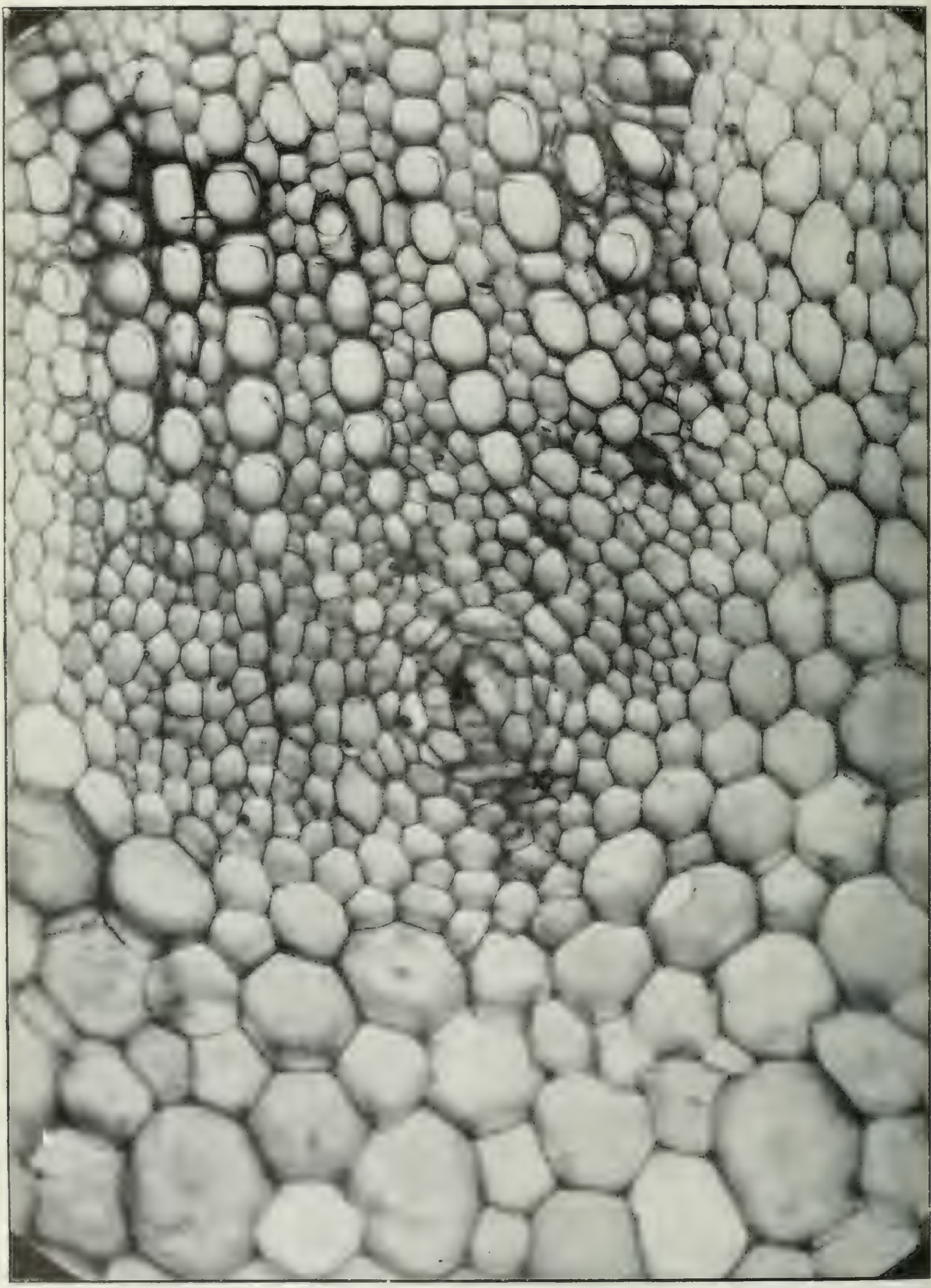
Daisy XIX. Cross section of petiole B, showing whorls in tumor tissue (p. 48).



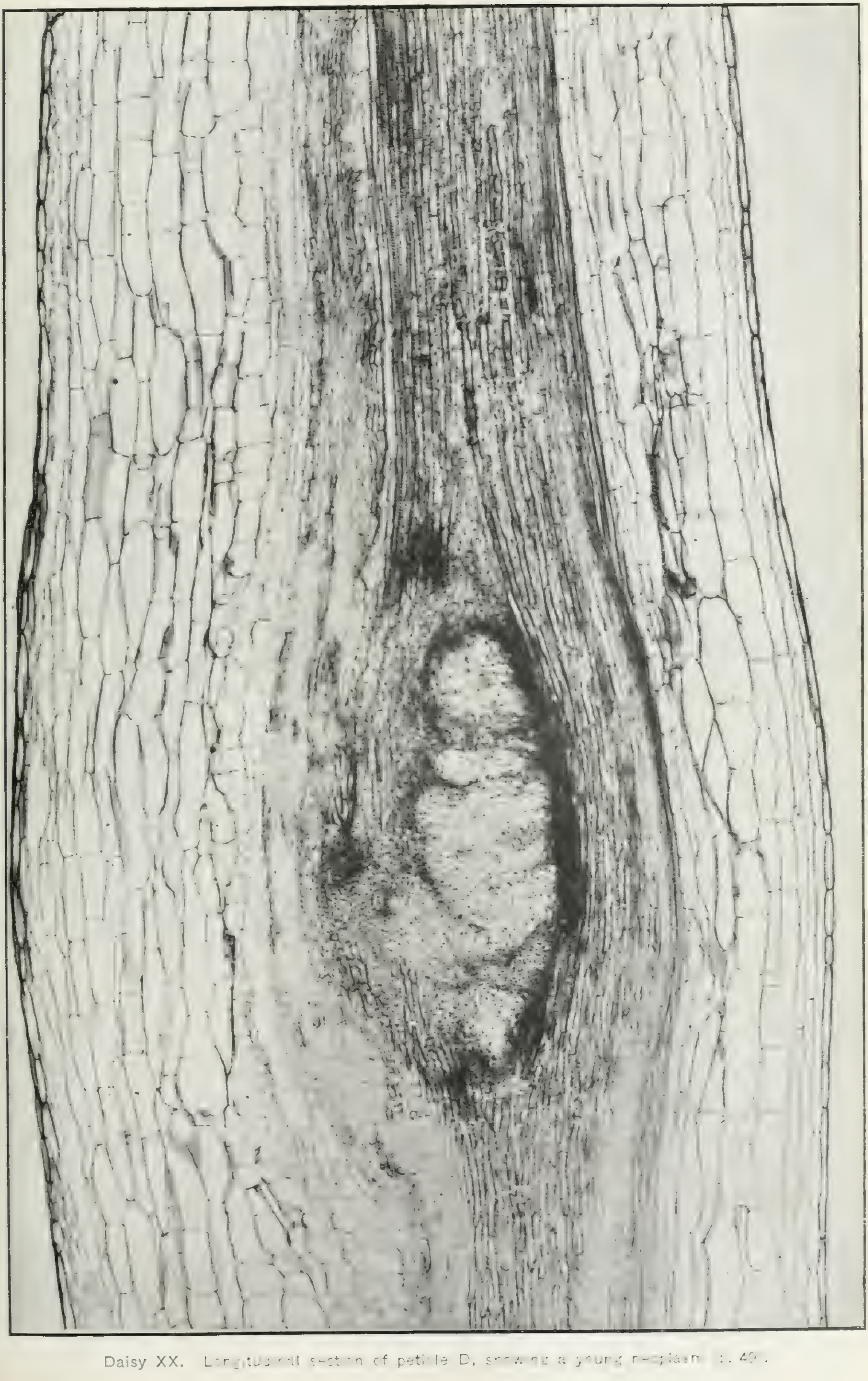
Daisy XIX. Cross section of base of petiole B in region of tumor-strand (p. 48).



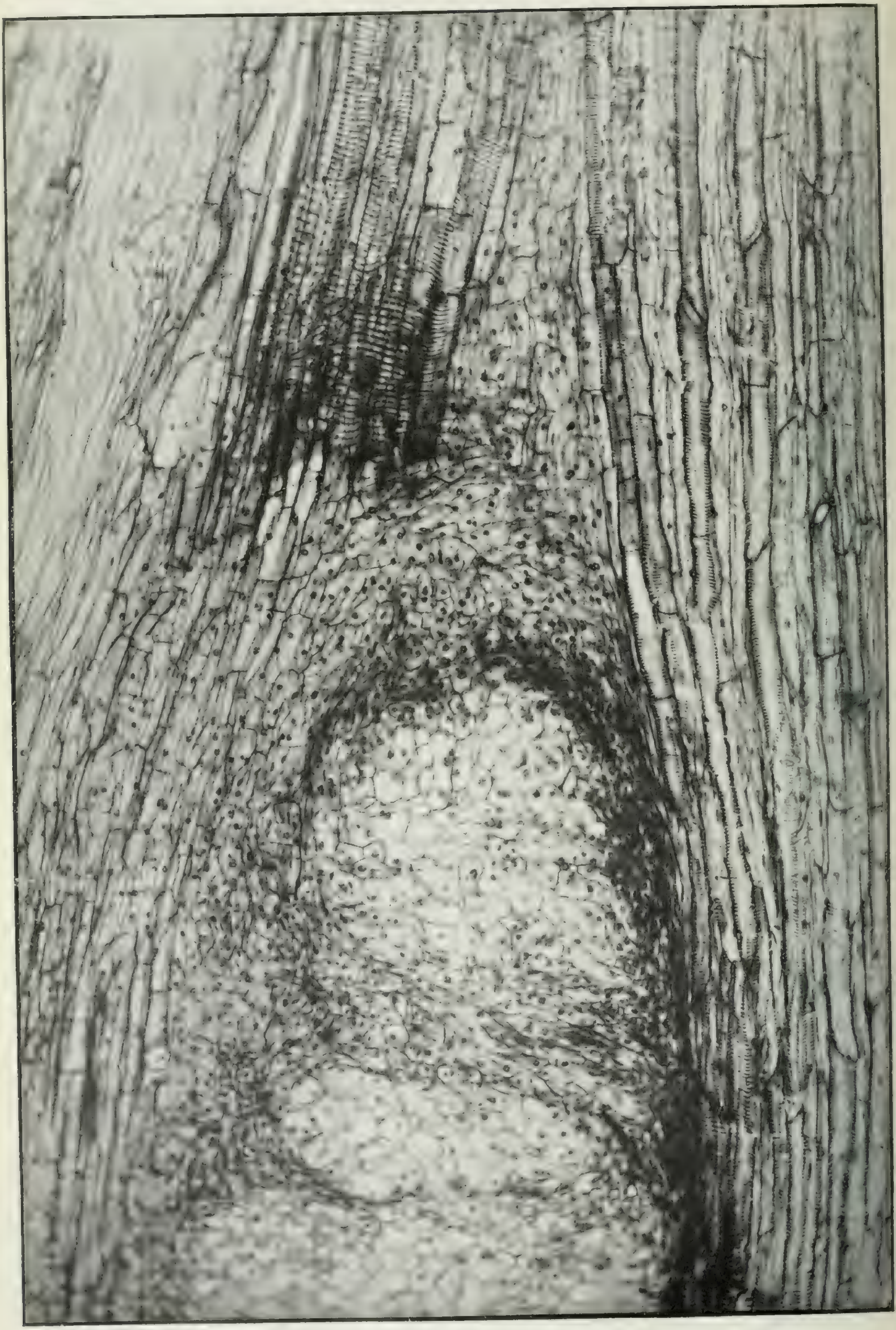
Daisy XX. Primary stem tumor and secondary leaf tumors; also a cross section of stem at 1 (p. 48).



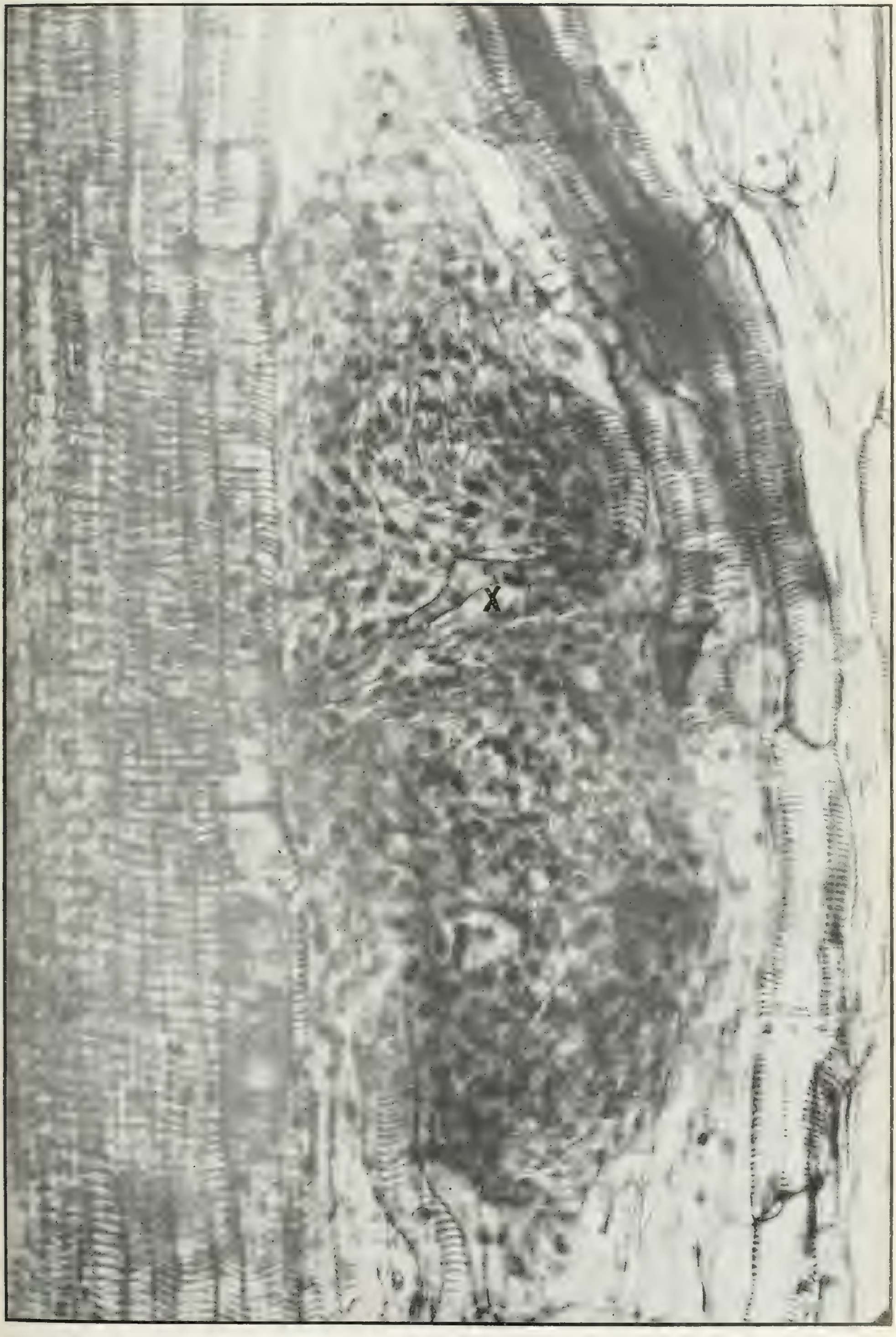
Daisy XX. Cross section of stem between tumors, showing small tumor-strand (p. 49).



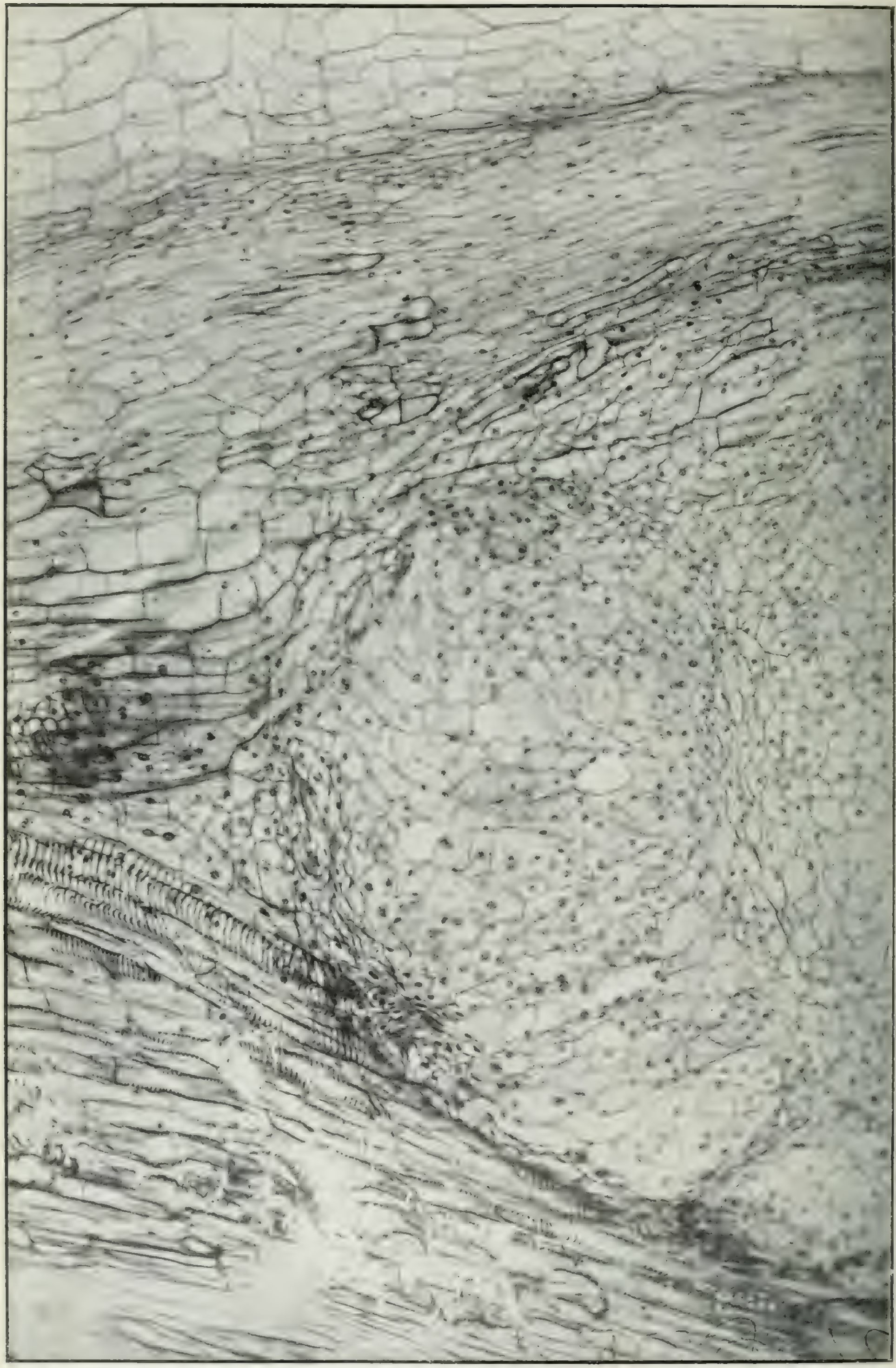
Daisy XX. Longitudinal section of petiole D, showing a young neoplasm (× 45).



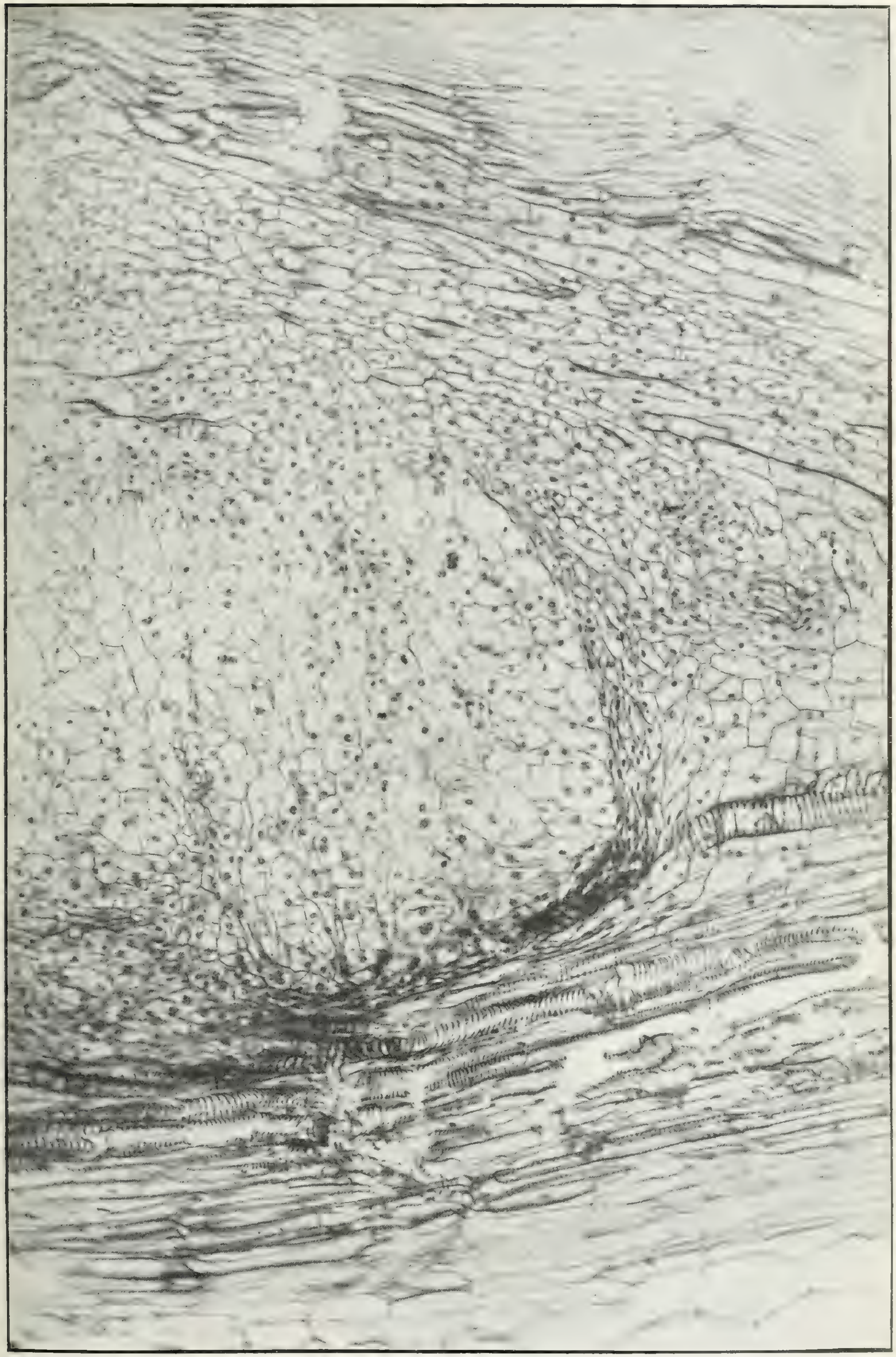
Daisy XX. Upper end of small neoplasm shown on Plate LXXXVIII (p. 49).



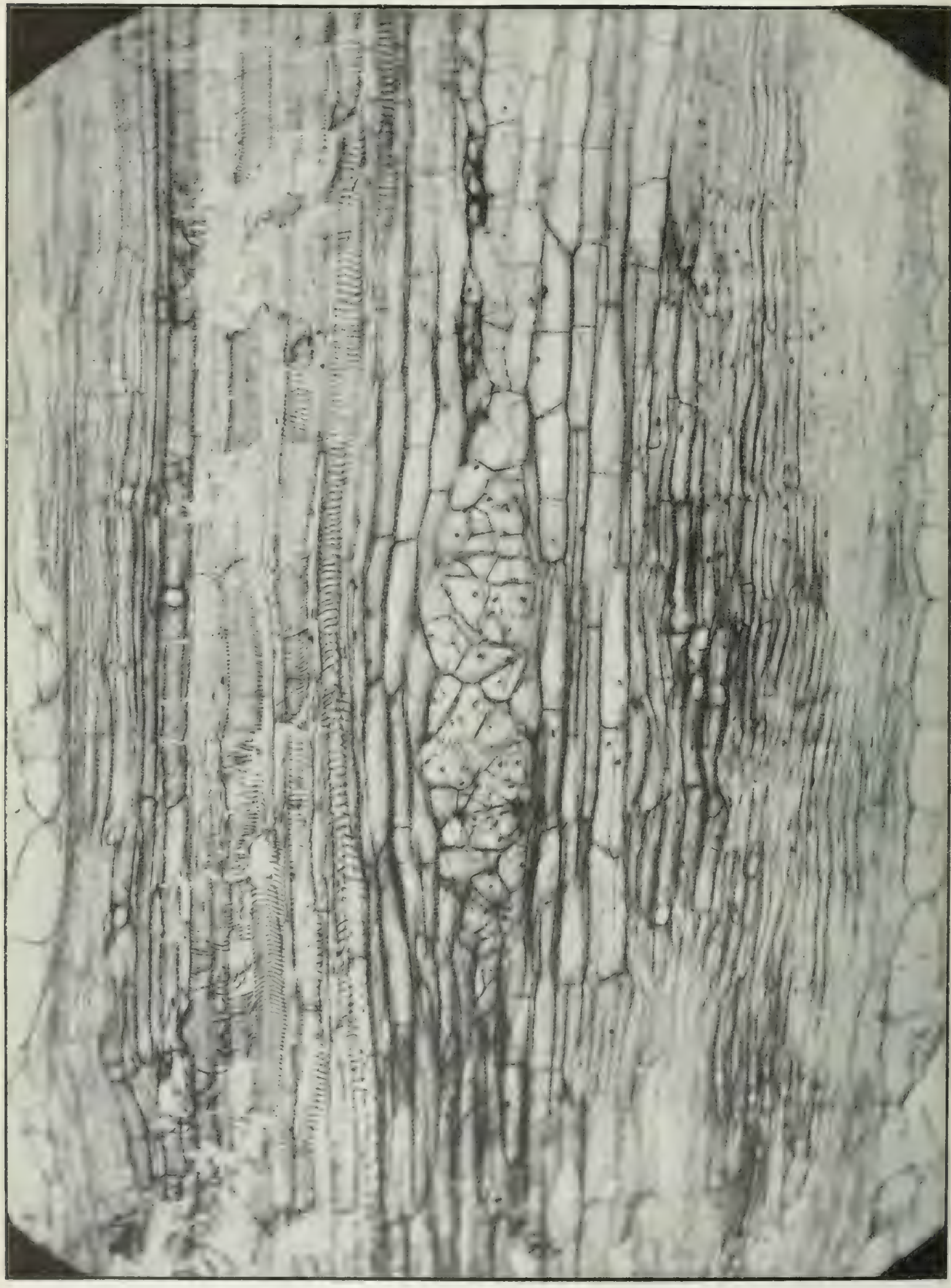
Daisy XX. Margin of small neoplasm, showing spirals wedged apart, and abnormal tracheids at X (p. 49).



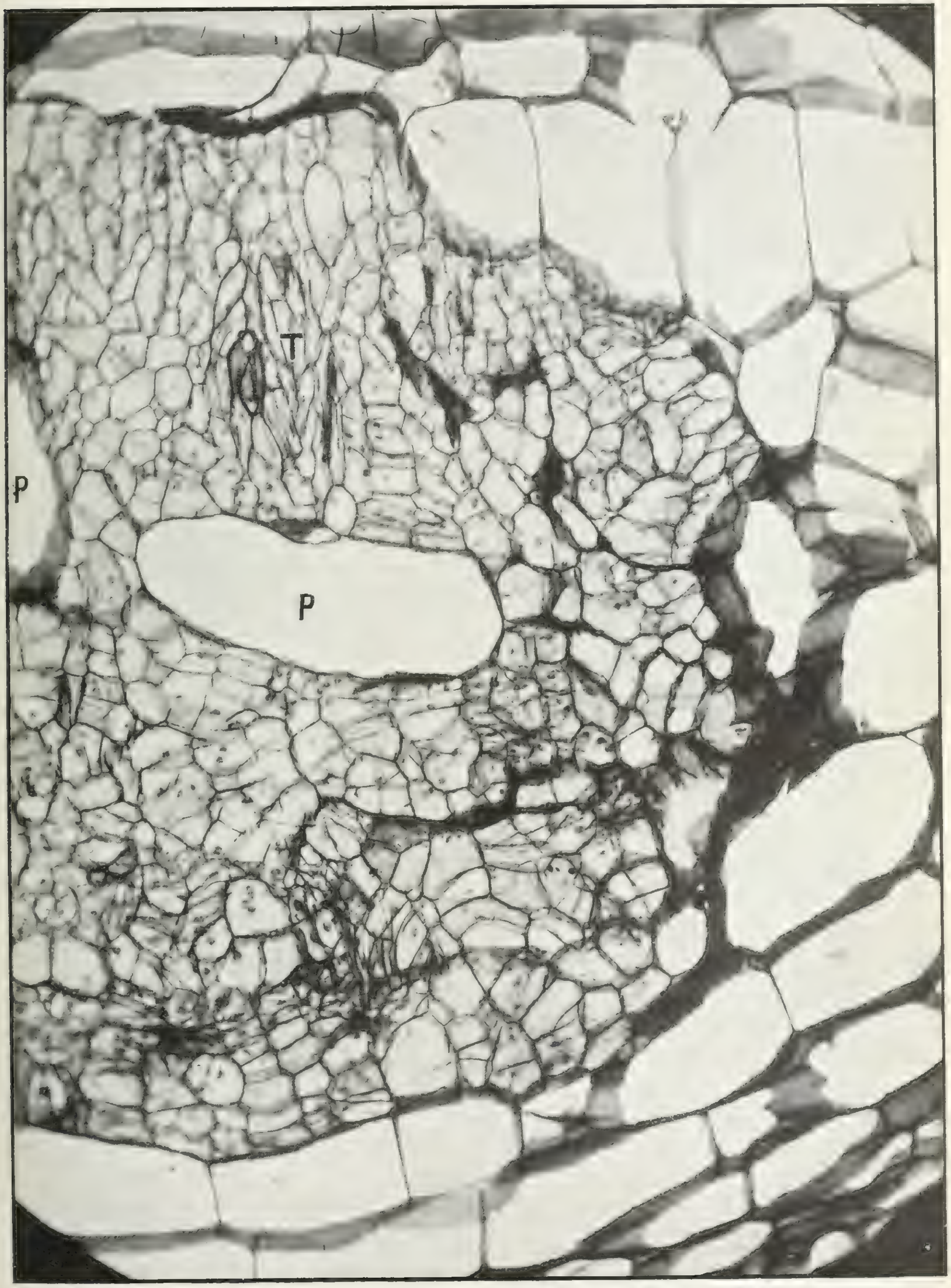
Daisy XX. One end of small unruptured tumor in petiole D (p. 49).



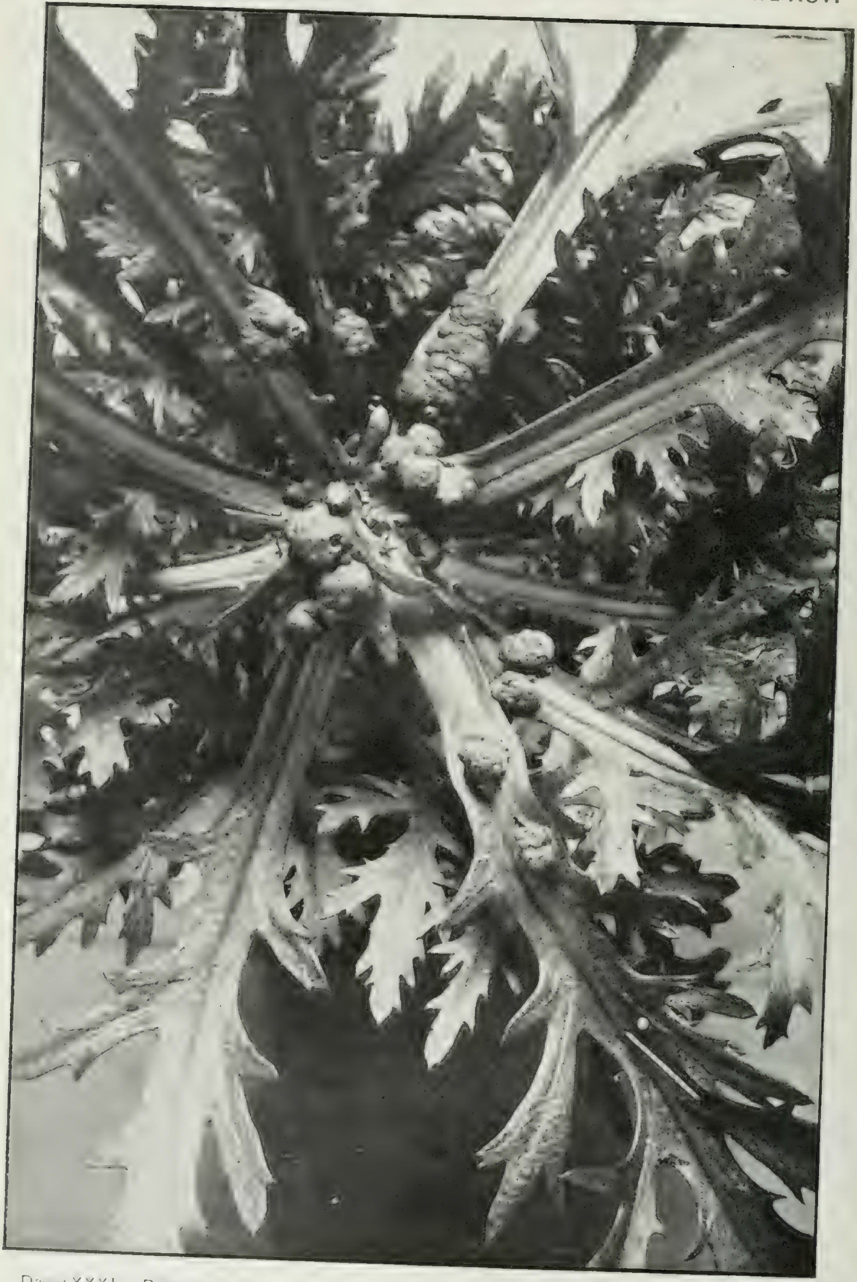
Daisy XX. Same as Plate XCI, but from the other end of the tumor (p. 49).



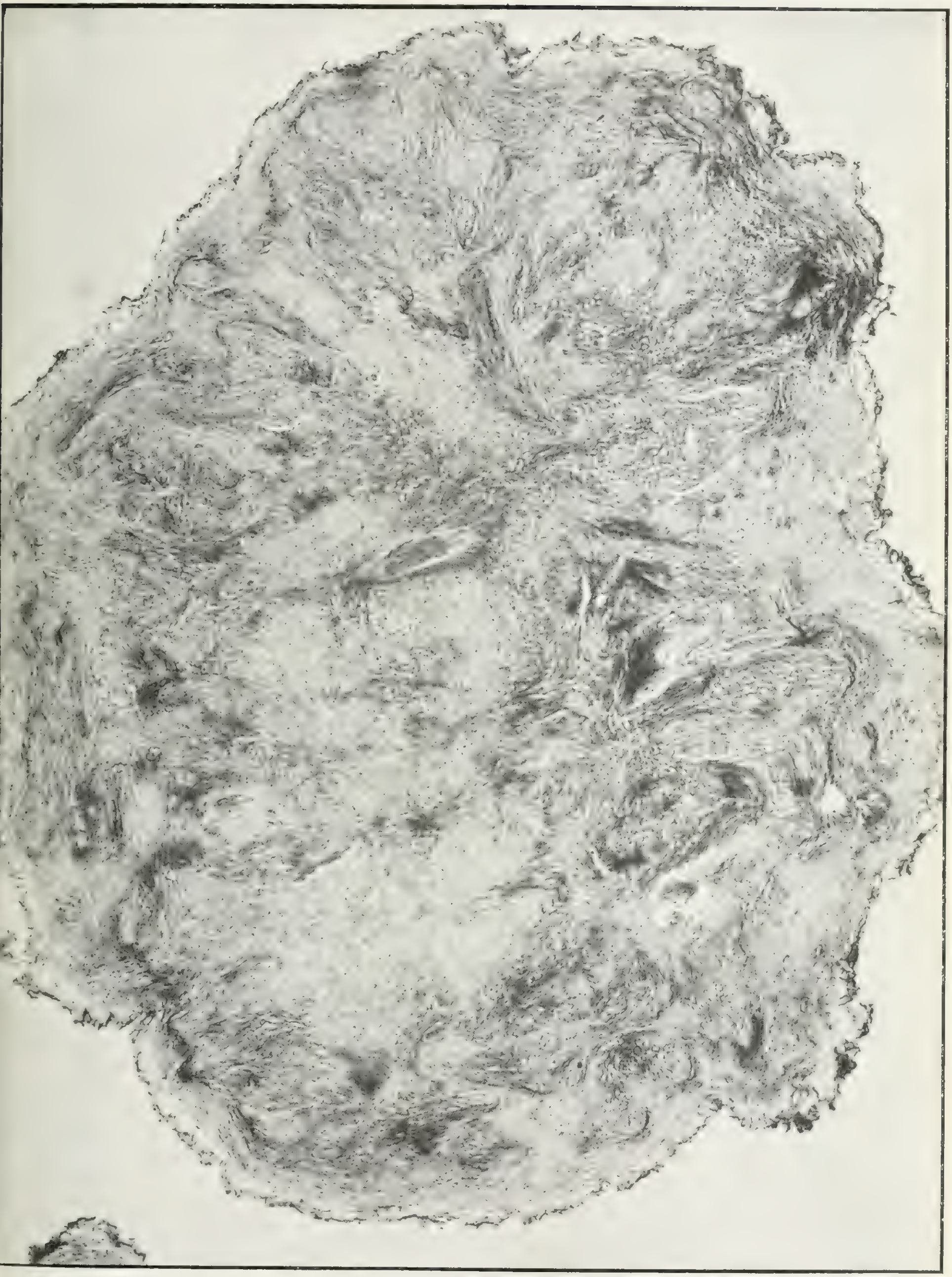
Daisy XX. Continuation of tumor-strand in petiole D (p. 50).



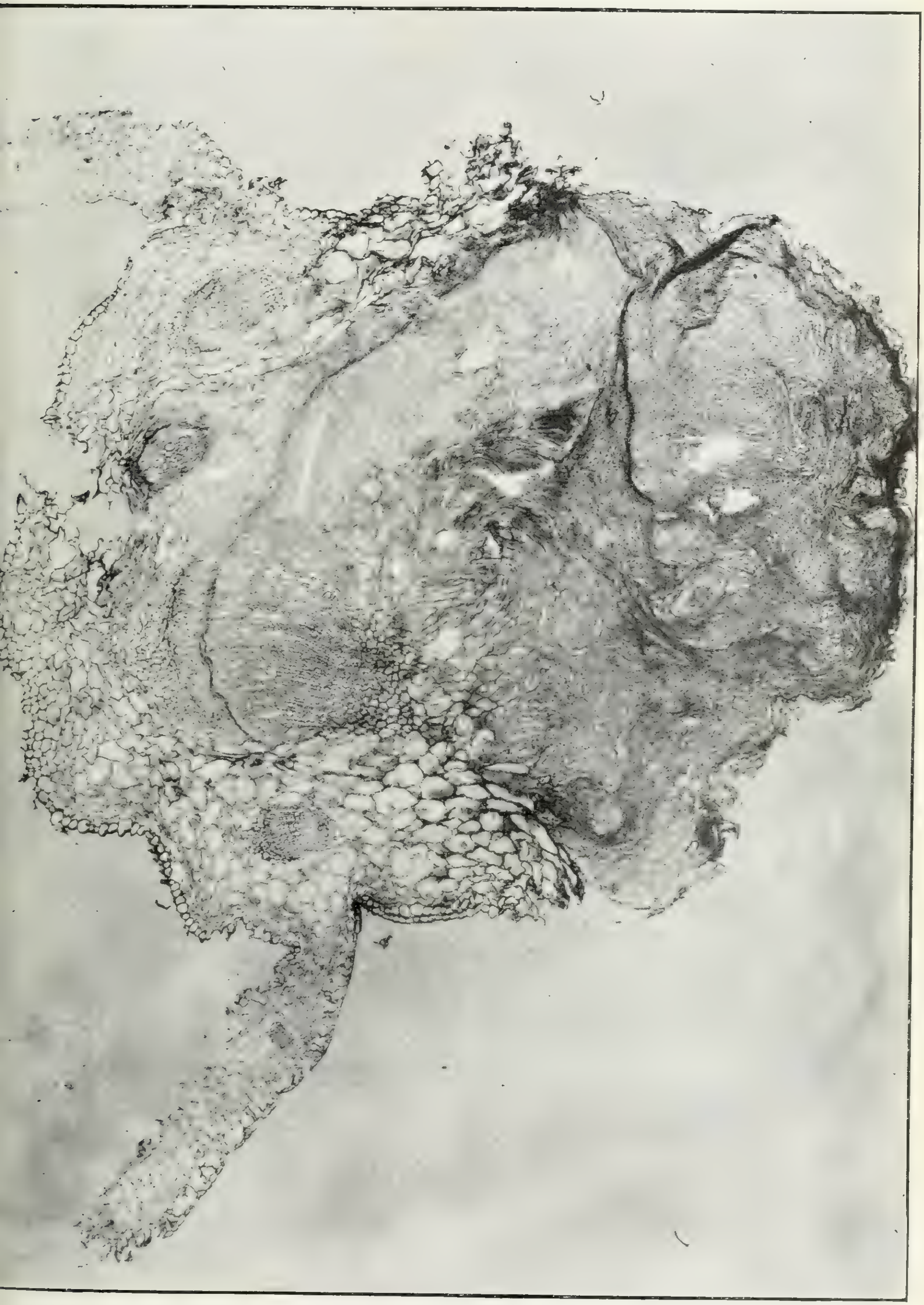
Daisy.—Margin of a tumor in a leaf stalk, showing tracheids at T, and inclusions of petiole parenchyma at P; at the right, ordinary ground tissue of the petiole (p. 50).



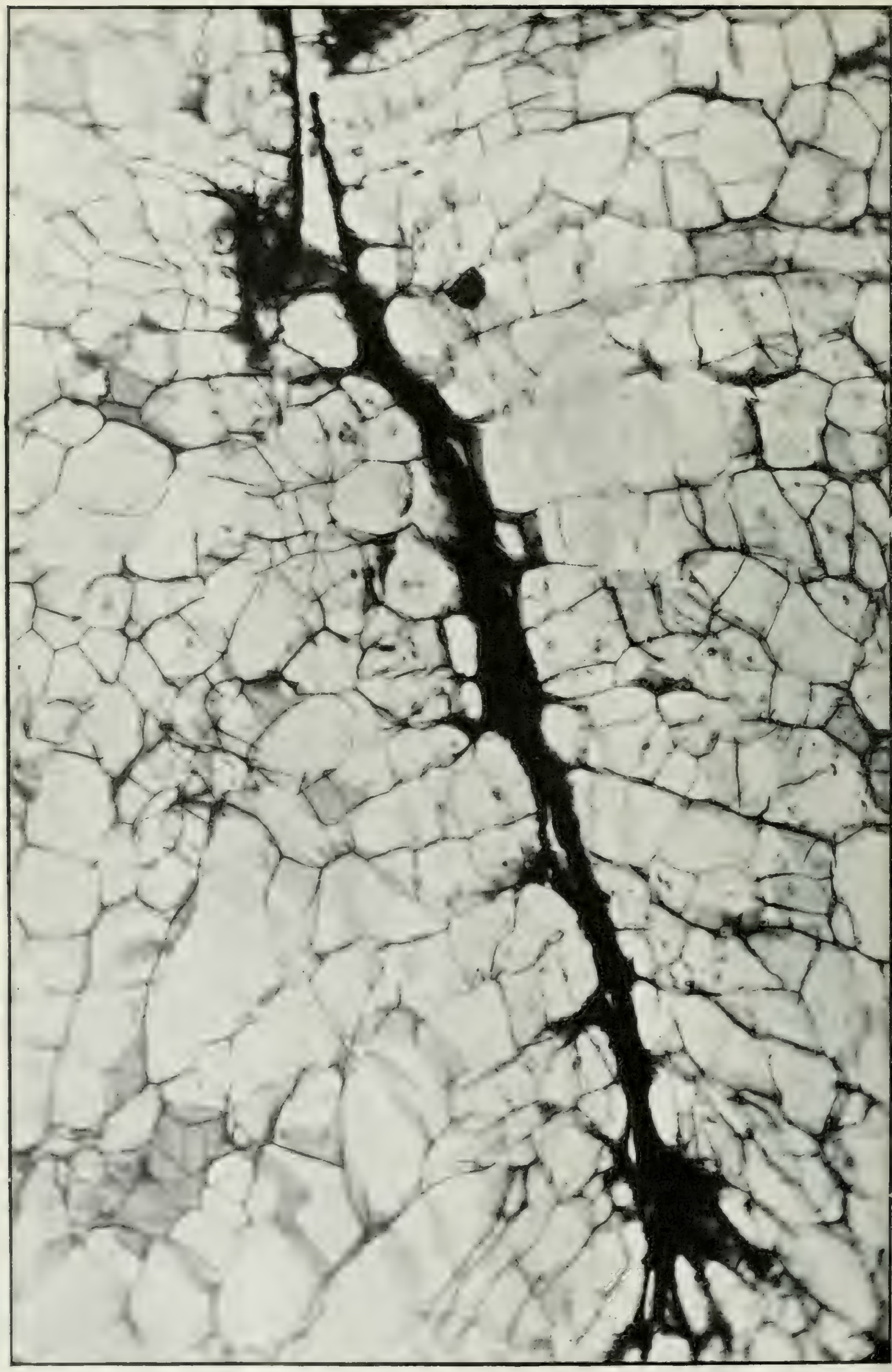
Daisy XXXI. Primary tumors on leaves (p. 50) resulting from single needle-prick inoculations introducing Bacterium tumefaciens. These galls do not have stem structure. For details, see next plate.



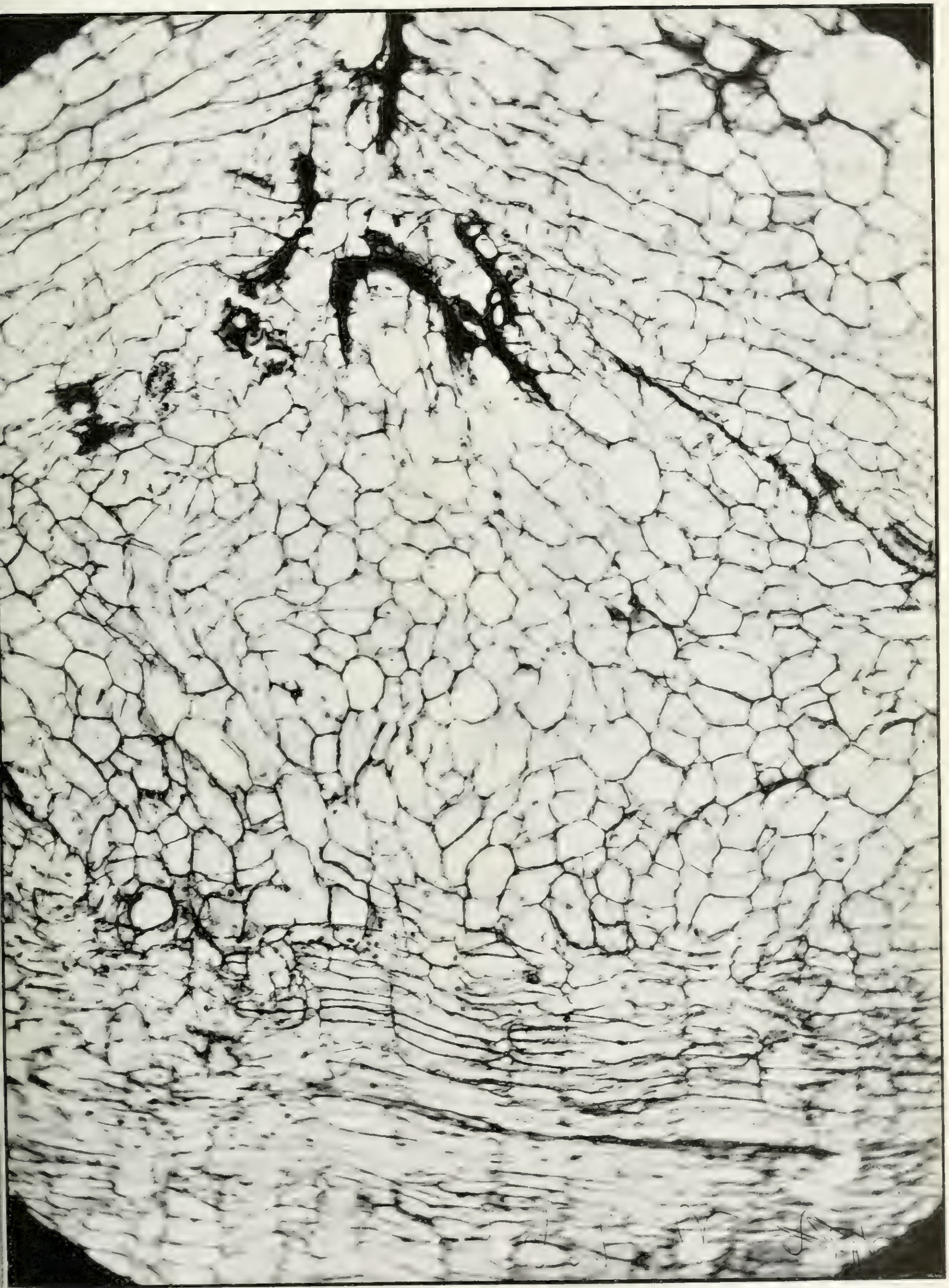
Daisy XXXI. Cross section of a primary leaf-tumor, for comparison with any of the secondary leaf-tumors, e. g., Plate LV. The numerous minute dots are deep-staining nuclei (p. 50).



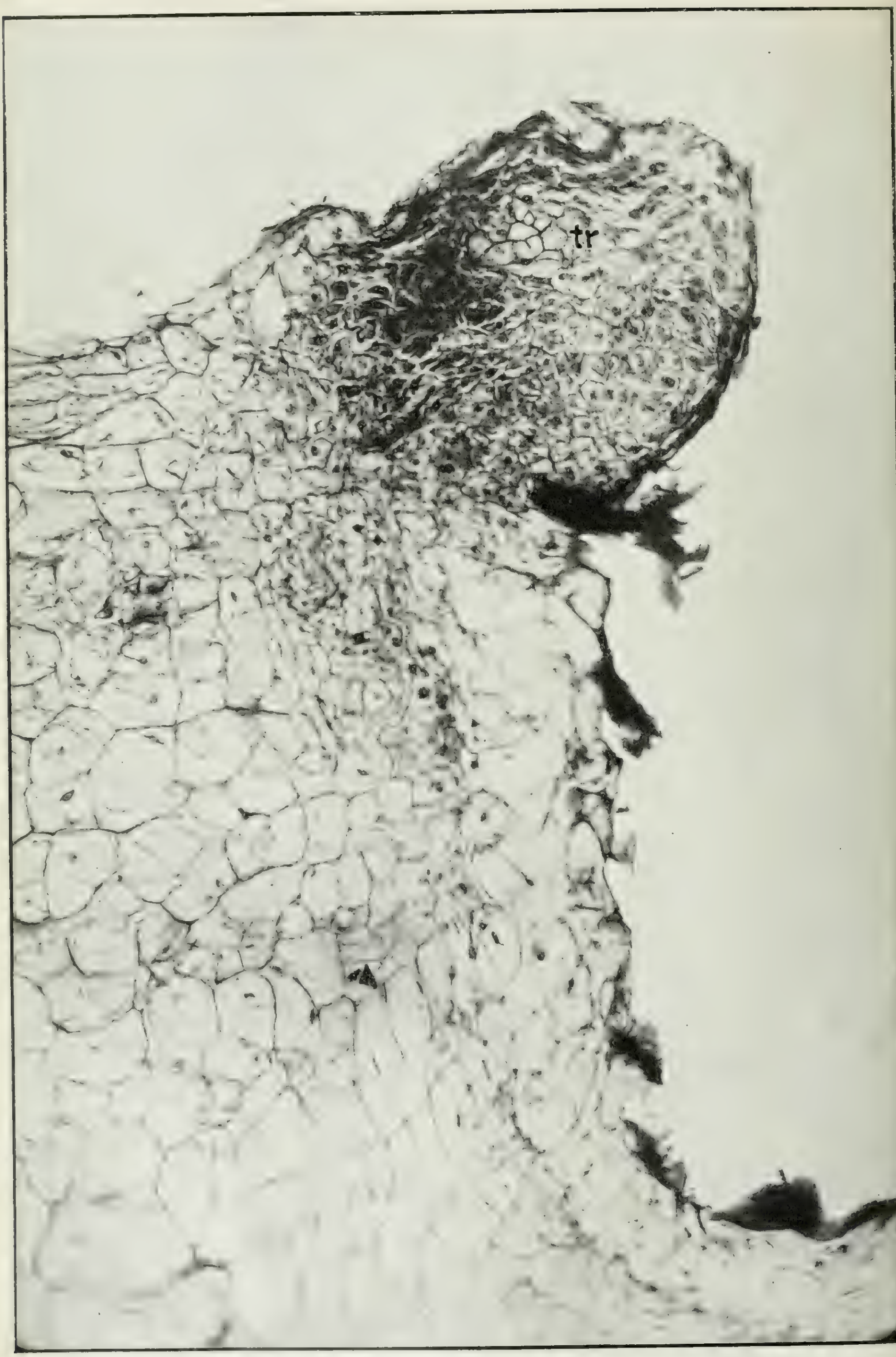
Daisy XXXI. Vertical section of another primary leaf tumor; normal part at the left (p. 50).



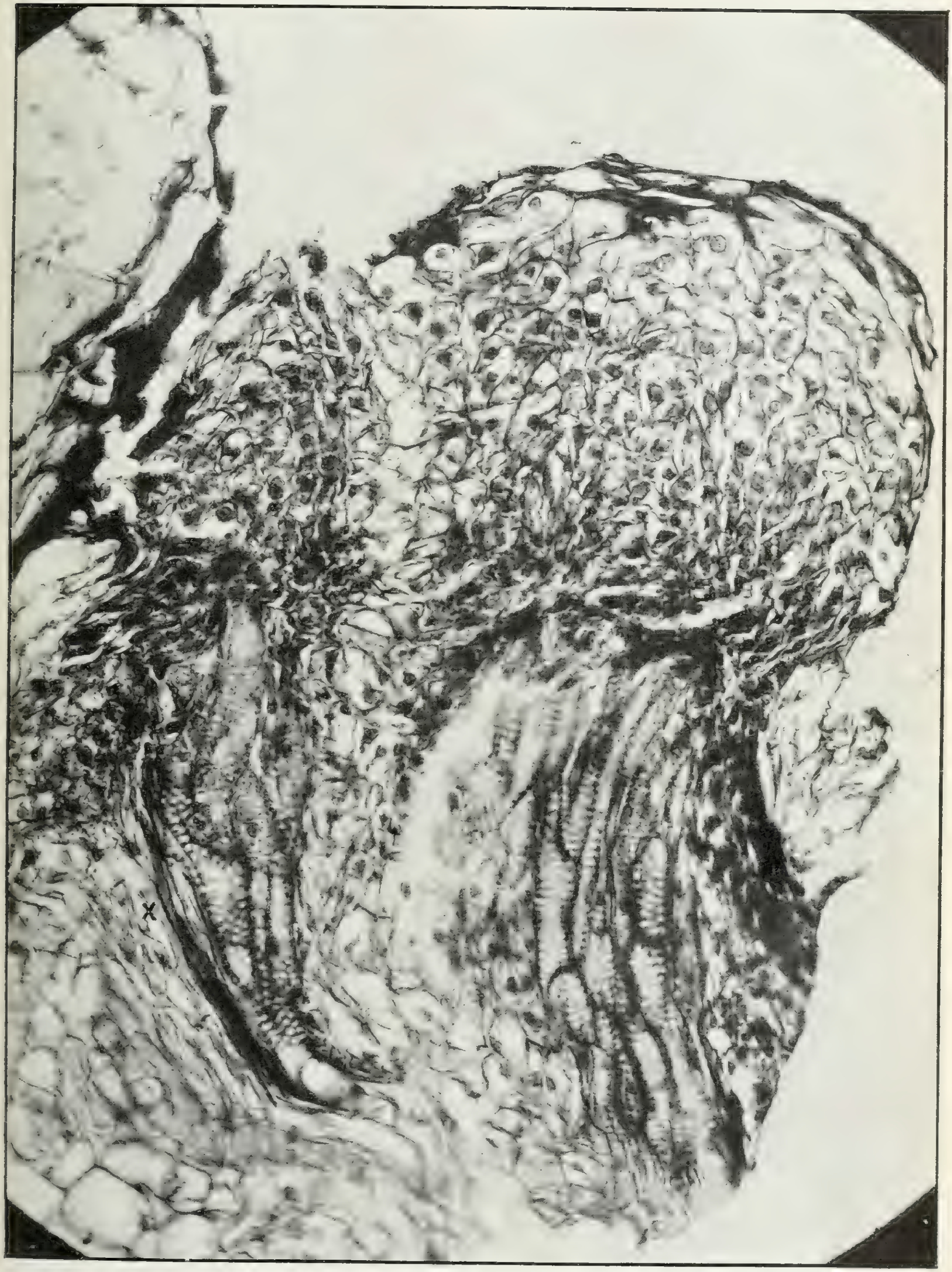
Tobacco. Infected needle-track through pith; no proliferation (p. 50).



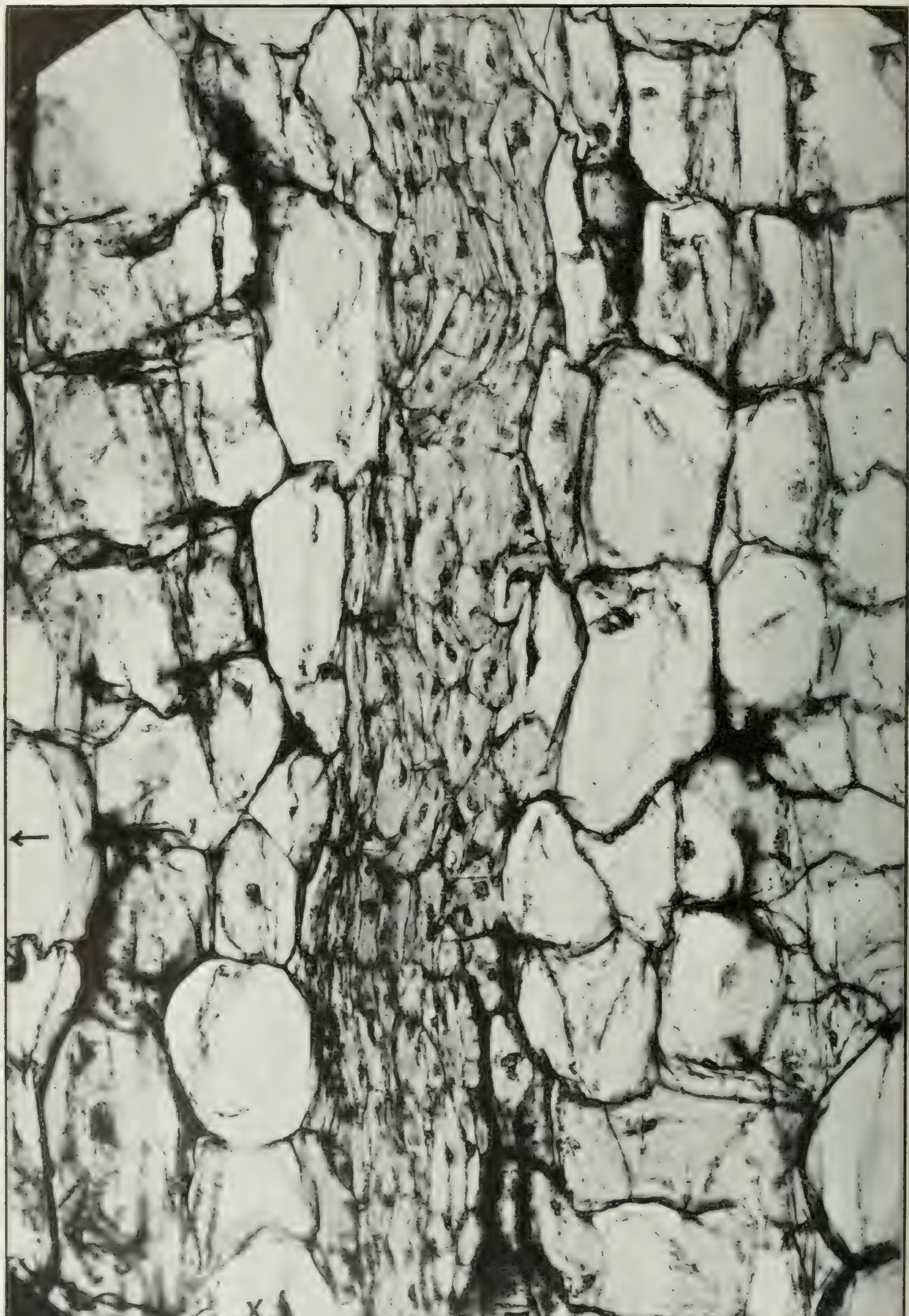
Tobacco. Longitudinal radial section, showing infected needle-track in cambium region with cells proliferating (p. 51). Time, 3 weeks.



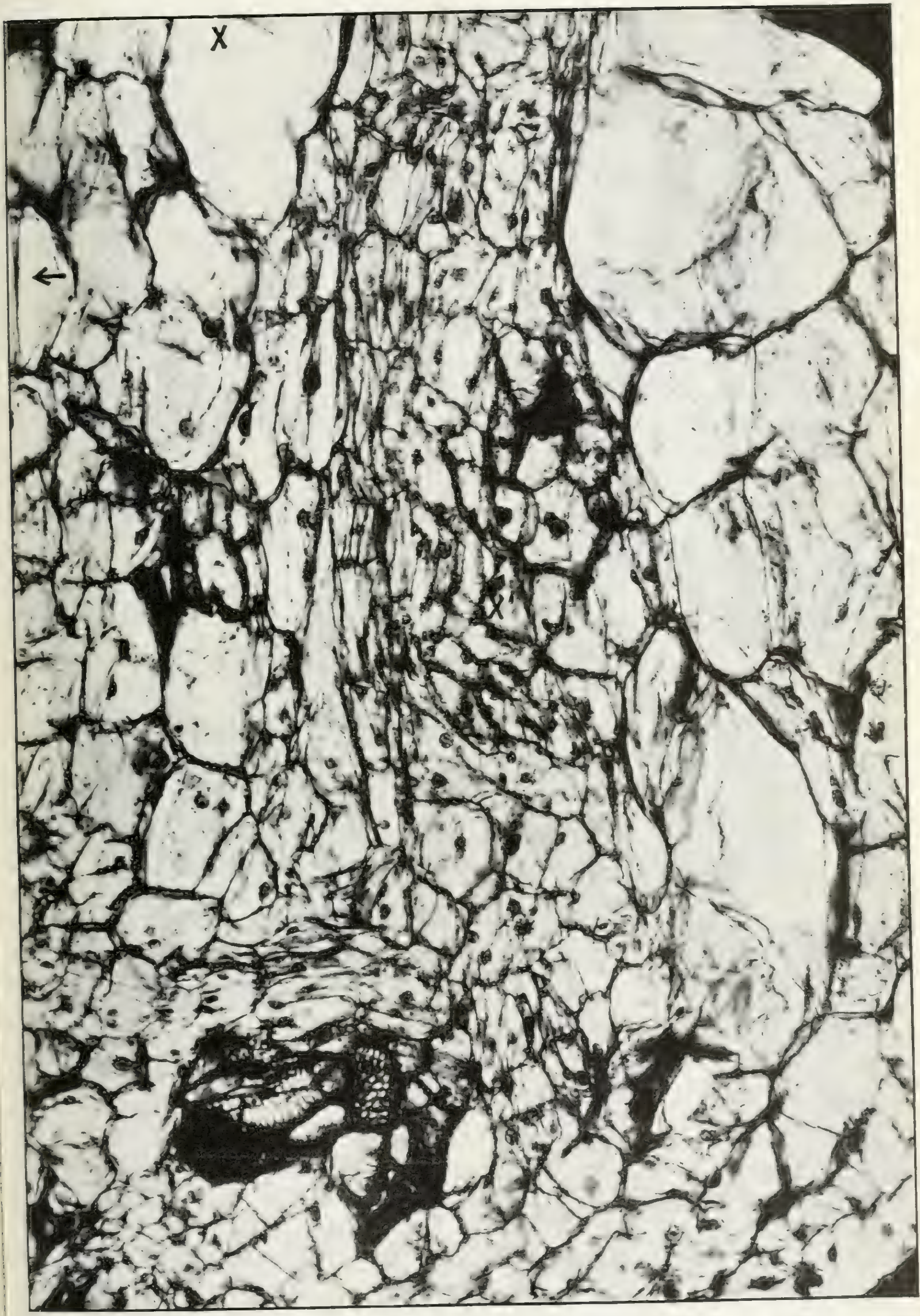
Tobacco. Margin of infected needle wound, showing tumor at top (p. 51).



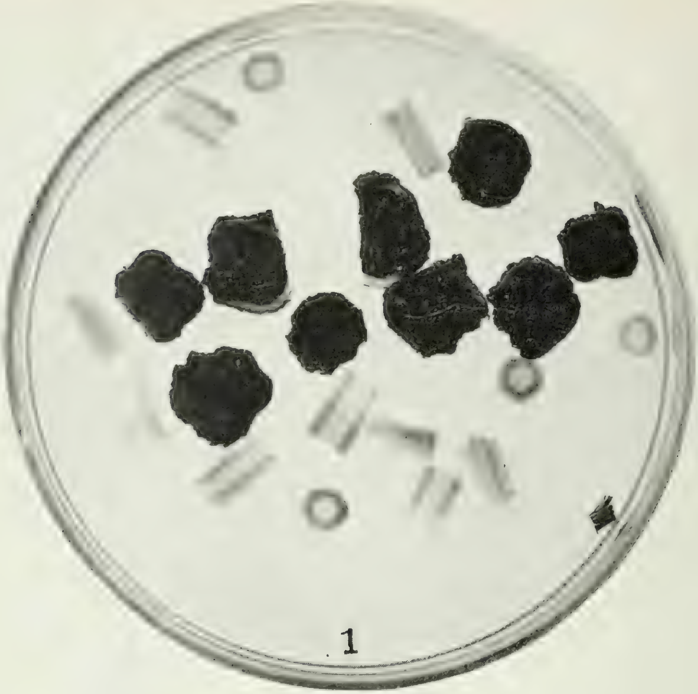
Tobacco. Margin of infected needle wound. Tumor in middle part of bark parenchyma; sieve tubes at X (p. 51).



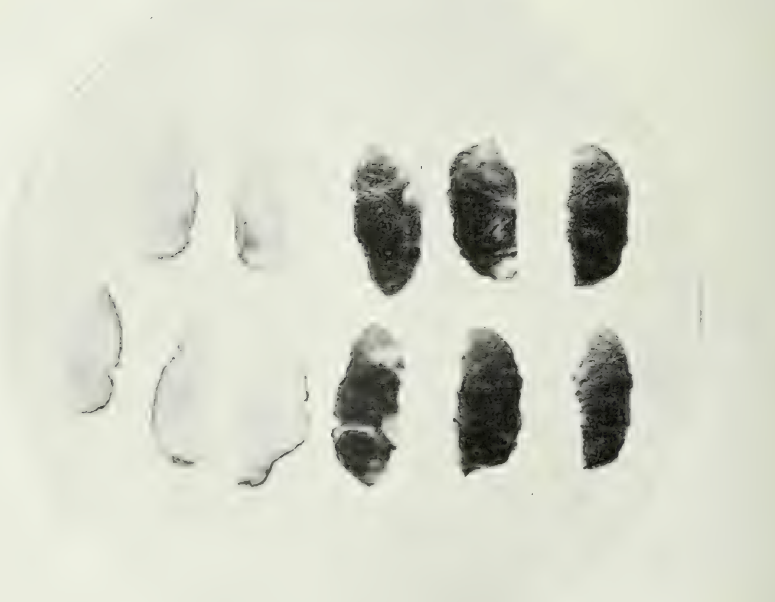
Tobacco. Tumor-strand in cortical parenchyma. Bottom joins top of next plate (p. 51).



Tobacco. Tumor-strand with tracheids in cortical parenchyma (p. 51).

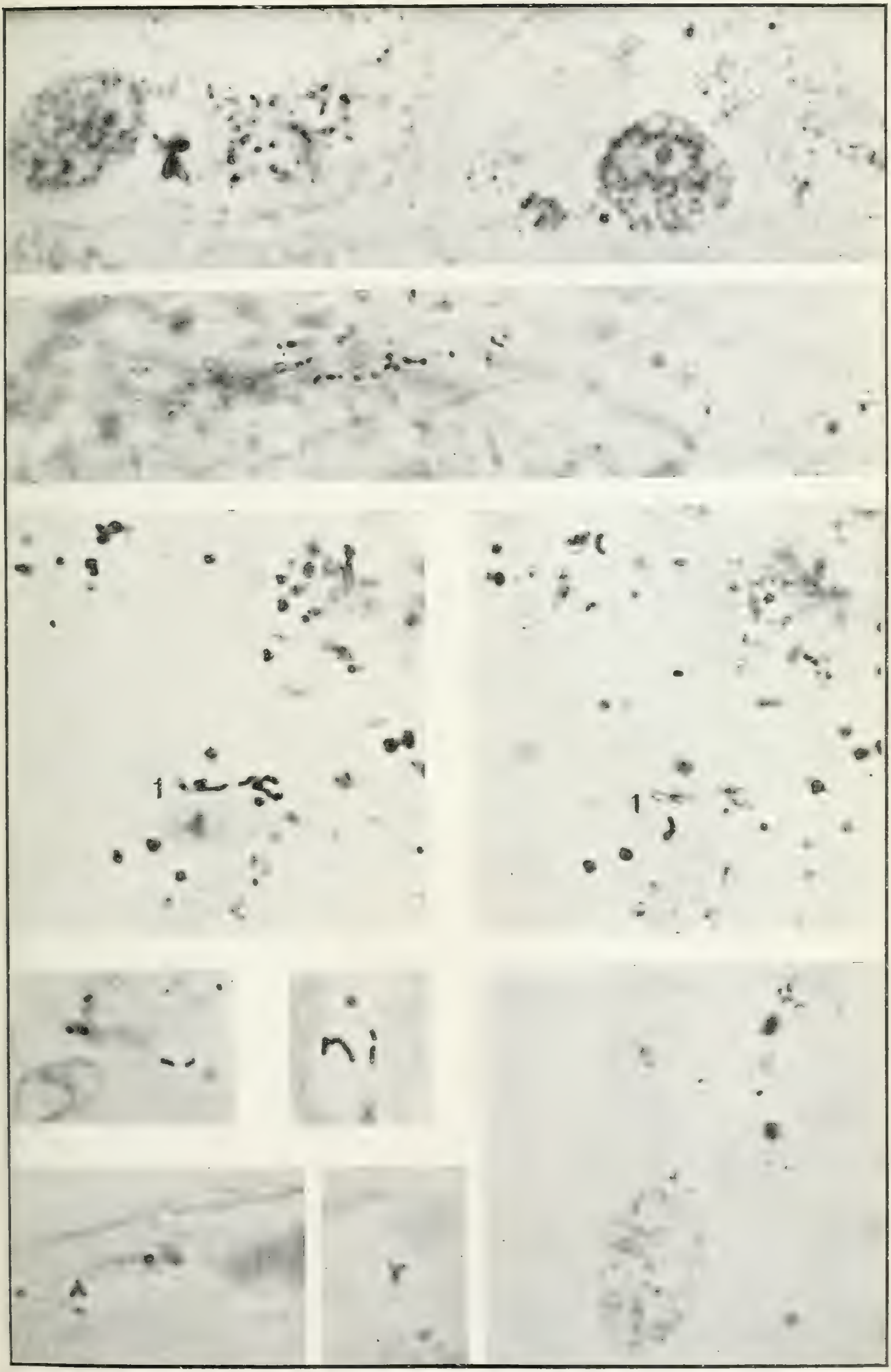


1

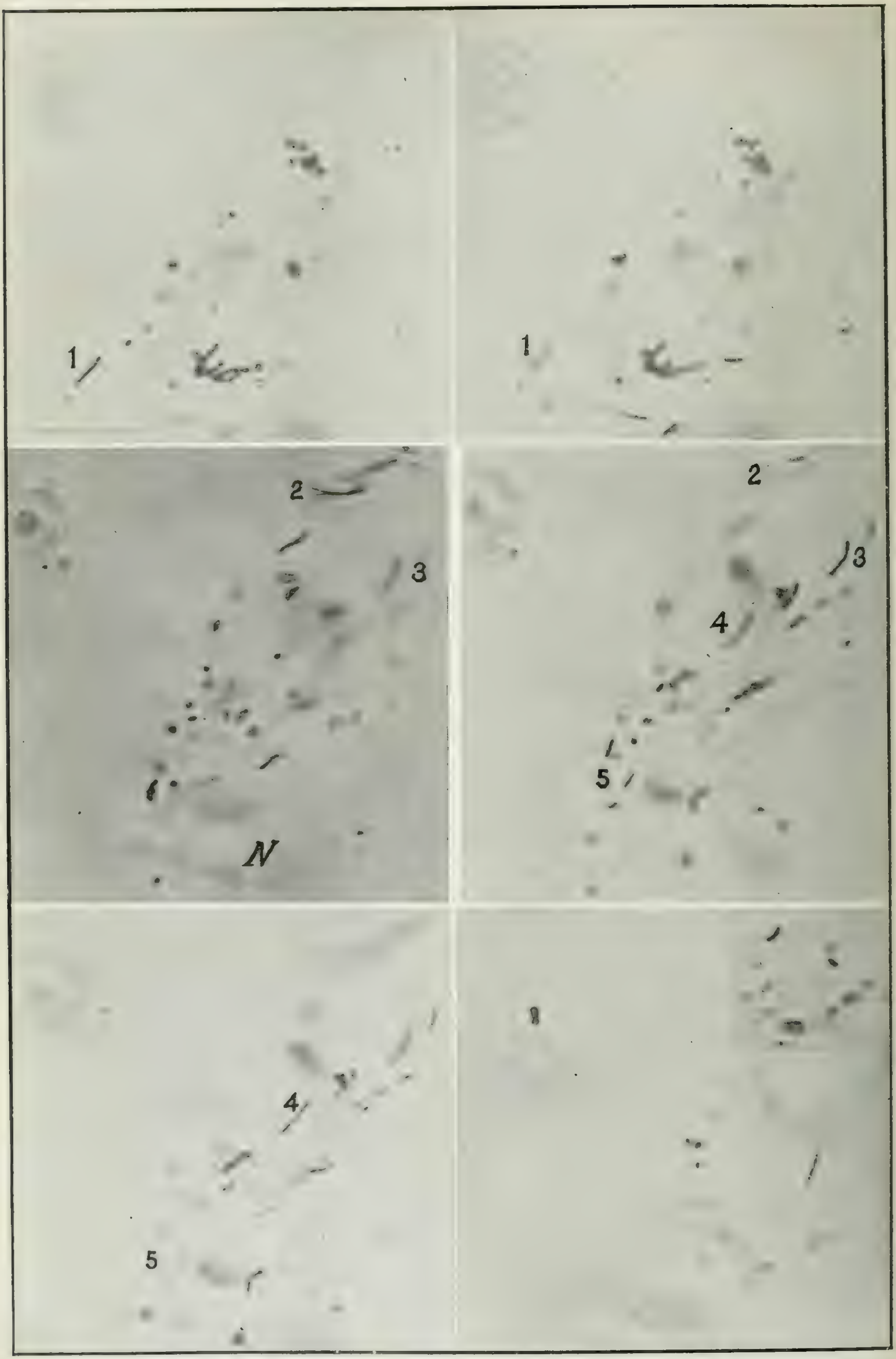


2

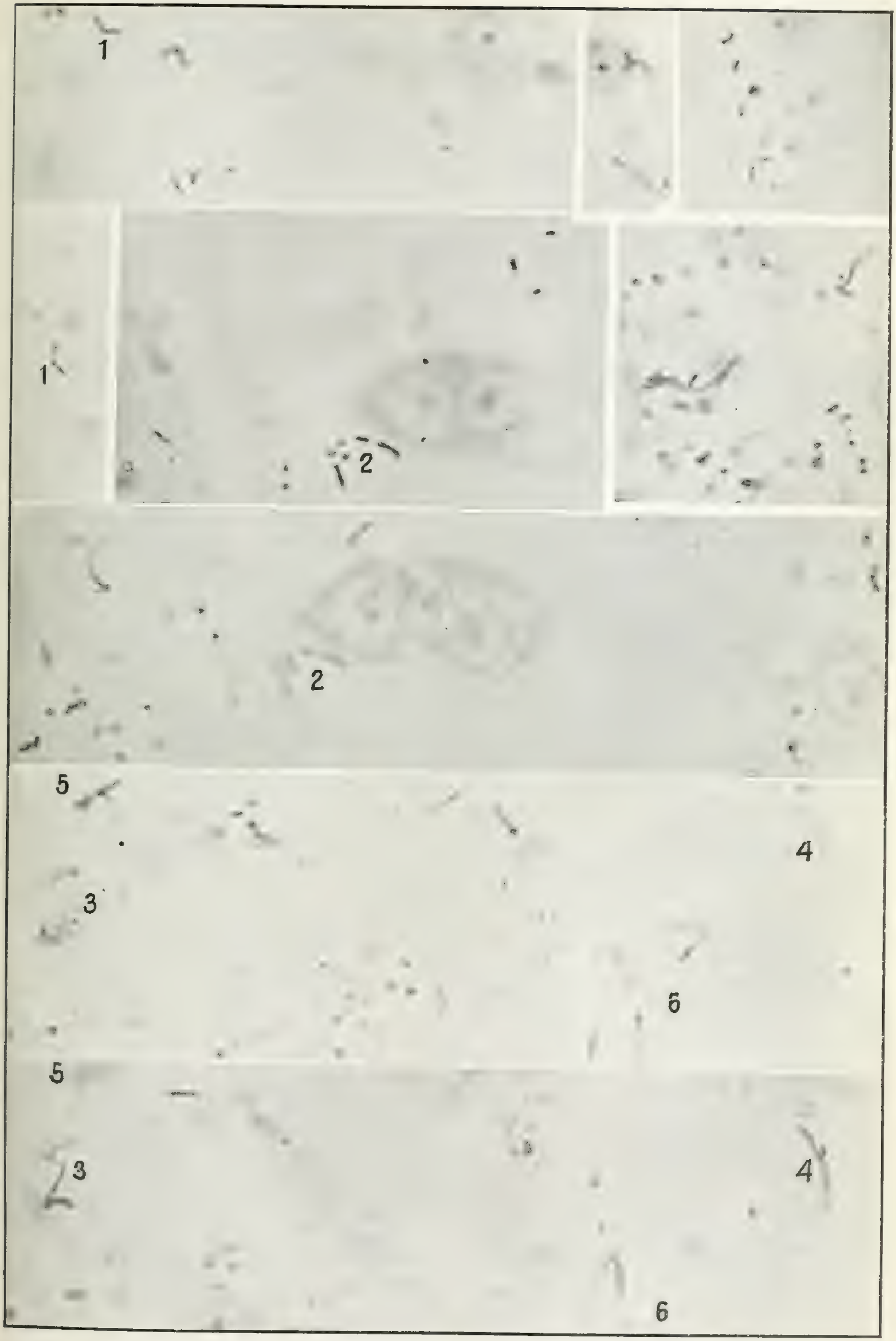
Daisy tumor. Reaction with chromium salts (pp. 23 and 51).



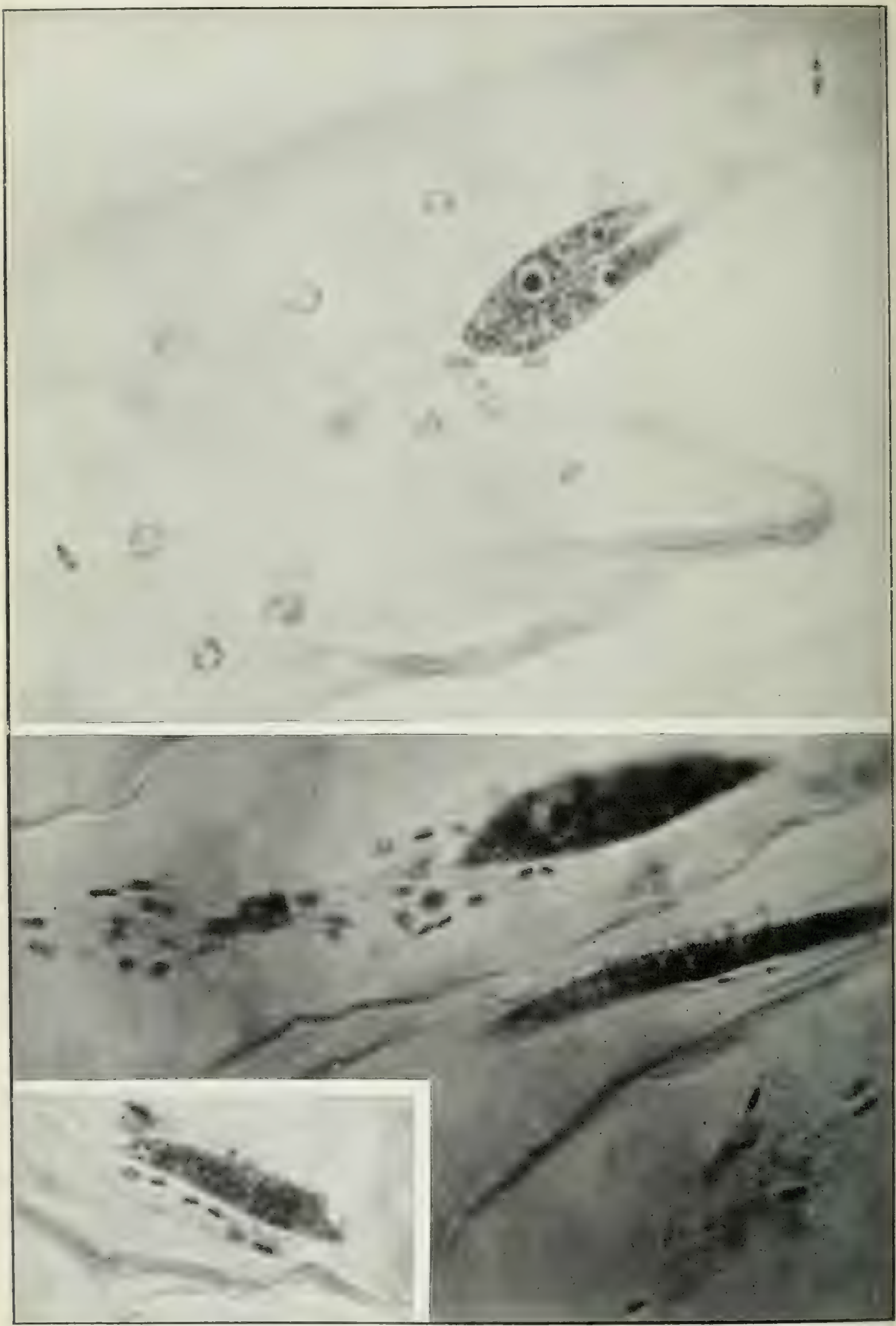
Daisy tumor. Gold-chloride impregnations (p. 52), showing bacterial rods and Y-bodies within the cells. X 2000.



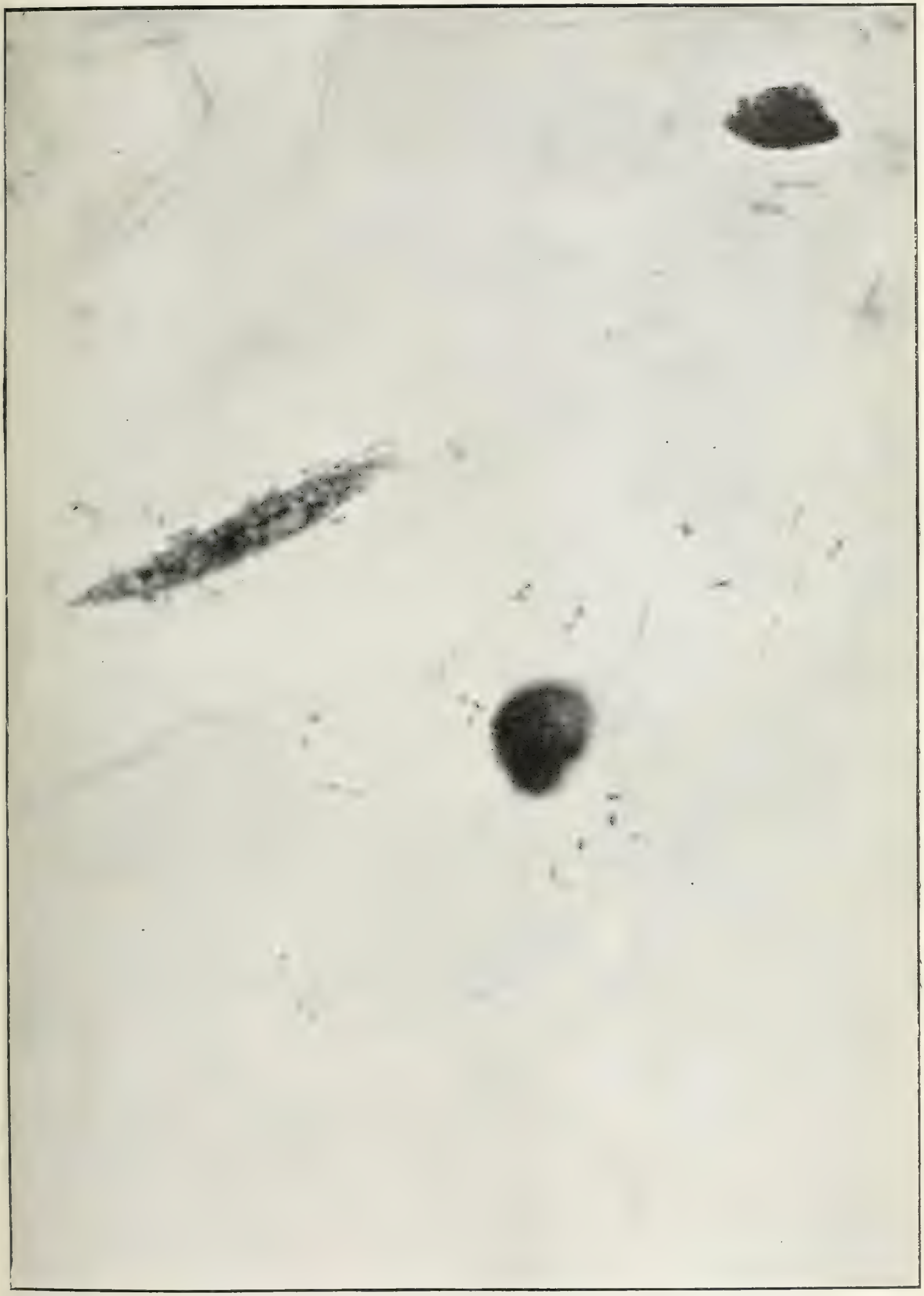
Daisy tumor. Gold-chloride impregnations (pp. 18, 19, 52), showing eight levels in a cell containing bacterial rods. X 2000.



Daisy tumor. Gold-chloride impregnations (p. 52), showing bacterial rods and Y's in various cells. X 2000.



Daisy tumor. Amyl Gram stain. Nuclei and chloroplasts which, when seen edge on, resemble bacteria (pp. 19 and 53). Upper nucleus dividing amitotically. X 2000.



Daisy tumor. Amyl Gram stain over washed, showing nuclei and rod-shaped bodies believed to be normal constituents of the cell (p. 53). The lower nucleus out of focus in order to make the other bodies distinct. X 2000.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 256.

B. T. GALLOWAY, *Chief of Bureau.*

HEREDITY AND COTTON BREEDING.

BY

O. F. COOK,

Bionomist in Charge of Crop Acclimatization and Adaptation Investigations.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry.
Office of the Chief,
Washington, D. C., May 25, 1912.

Sir: I have the honor to transmit herewith a paper entitled "Heredity and Cotton Breeding," by Mr. O. F. Cook, Bionomist in Charge of Crop Acclimatization and Adaptation Investigations, and to recommend its publication as Bulletin No. 256 of the bureau series.

This paper outlines some new methods and standpoints for the study of heredity, with applications to practical problems in the breeding of cotton. It shows how problems of heredity and methods of breeding can be simplified by a more definite recognition of the fact that the expression of characters is distinct from transmission. In addition to these general results detailed information is given regarding the habits of the various types of cotton, the effects of external conditions, and the behavior of the different characters in heredity.

In addition to its use by other investigators and breeders, a general paper of this kind should render the subject of cotton breeding more interesting from the educational standpoint and assist extension workers in understanding and presenting to the farmer the reasons for the improved methods of selection that have been developed. Though the paper necessarily deals with scientific distinctions, technical terms are employed only when the meanings are explained by definitions or by reference to familiar facts.

Very respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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HEREDITY AND COTTON BREEDING.

INTRODUCTION.

The breeding of new varieties is no more difficult with cotton than with other plants, but the relation of heredity to the cotton crop does not end with the breeding of varieties. To preserve a superior variety so that it can be utilized for purposes of production is a more difficult practical problem than the breeding of a new variety, and requires an equally intimate acquaintance with the facts of heredity. On account of the industrial uses of the cotton fiber, uniformity is of much greater importance than with other field crops, but methods that secure uniformity in other crops are not applicable to cotton. The habits of the plant and the unorganized state of the industry seem to preclude the establishment of any centralized system of seed production.

The improvement of the cotton industry through the utilization of superior varieties is likely to require a large development of popular interest in the applications of heredity to cotton production. The methods of scientific agriculture are much more likely to secure effective application among those who understand the underlying facts that make such methods necessary. The farmer who undertakes to follow directions without understanding the reasons for them is likely to make but poor and ineffective use of any method that requires special care or skill.

The intelligent farmer has not only a material advantage to gain but also a much greater interest and satisfaction in his work, if he learns the reasons for what he is doing and is able to place a correct interpretation upon the characters and behavior of the plants that engage his attention. It is true that a special training is necessary for effective work in breeding and selection, in the sense that detailed knowledge is required, but it is a training that can be secured on the farm better than anywhere else. Moreover, the cotton plant affords unusual opportunities for gaining insight into the problems of heredity and breeding. Many of the complicated methods used on other plants by laboratory workers and statistical biologists are unnecessary with cotton, for reasons that are explained in this bulletin.

Direct, practical familiarity with the fact of heredity in such a plant as cotton is a much more effective training in plant breeding than any that the school can supply through the medium of formal instruction. The farmer who learns how to select his own cotton not only makes his crop more profitable but has something of real value to teach his children. In spite of the general tendency to assume that everything in the way of detailed knowledge must be learned in school, the educational possibilities of farm life are beginning to be appreciated. The development of a truly agricultural civilization will be assured when people understand that farm life has larger possibilities of human development than urban existence. Genuine farm education is needed—not merely agricultural courses in schools.

It is not expected that this bulletin can be made generally available for the purpose of home instruction in cotton breeding, nor is it intended for this purpose. Such a manual, containing detailed accounts of the characters and habits of the varieties, might be useful in educational work but is not yet available. The best way to become familiar with a variety of cotton is to study it in the field. Such study is facilitated by having a general point of view for understanding the facts, even more than by being told in advance exactly what should be seen. This bulletin states the general biological reasons for the methods of breeding and selection that have been suggested in previous publications of the Bureau of Plant Industry.[1]

A recognition of the general relations of heredity to cotton breeding is the first requisite for placing the subject on an adequate scientific basis. The real task of agricultural investigators, experiment station workers, and other agencies enlisted in the improvement of the cotton industry is the education of the cotton-growing public, so that better cotton can be grown. But the experts must first understand the problem, if their teaching is to benefit the public.

It is not safe to prescribe methods of cotton breeding merely on a basis of analogy with other crops. The methods developed for cereals and other self-fertilized plants are not adequate. A much wider range of biological facts must be taken into account in the breeding and selection of open-fertilized plants like cotton. Indeed, the problem of preserving and utilizing superior varieties of cotton has important economic and educational aspects, for it can not be solved by the individual farmer working alone, but requires the organization of cotton-growing communities devoted to the production of a single type of cotton. Hence the need of a general statement of the underlying principles or physiological factors of heredity that have to be applied in the breeding and selection of cotton.

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[1] Local Adjustment of Cotton Varieties, Bulletin 159, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909. Cotton Selection on the Farm by the Characters of the Stalks, Leaves, and Bolls, Circular 66, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1910. Cotton Improvement on a Community Basis, Yearbook, U. S. Dept. of Agriculture, for 1911, pp. 397–410.

Facts of nature have an interest of their own, apart from any general inferences or applications. As Emerson has said, "Nature is loved by what is best in us." But when practical applications are to be made the facts must be interpreted. Investigators of heredity propose to apply their results to the breeding of improved plants and animals, and even to human eugenics. In drawing conclusions for such purposes the utmost caution is required, not only in basing our inferences on large numbers of facts but in distinguishing different kinds of facts and understanding their relations to each other.

Investigating facts from the wrong point of view is like traveling on the wrong road. Instead of bringing us nearer to the end of our journey, the most diligent effort may only expose us to unexpected dangers. To give advice on breeding problems without taking the underlying physiological factors into account is to invite disaster and confusion. Many attempts have been made to establish a distinction between pure science and applied science, the assumption being that more careful or fundamental researches are made when no practical objects are in view. But in reality the most complete and adequate knowledge is required to meet the test of practical application and thus open the way to further progress.

THE NATURE OF HEREDITY.

Heredity, the resemblance of offspring to parents and ancestors, is one of the most familiar facts of nature and yet one of the most mysterious. Nobody has been able to imagine any sort of mechanism that would perform the work of heredity, much less a mechanism of the nature of a fluid jelly, like the protoplasm of the living cell. The first theory of heredity assumed that the new organism was preformed in the egg as a minute model that developed to visible size after fertilization. This notion was long since given up, but the idea of models or other determining mechanisms continues to serve as the basis of speculation regarding the nature of heredity. Though it is no longer expected that the microscope will reveal infinitesimal plants or animals swimming in the protoplasm, the hope is still cherished that something in the protoplasm of germ cells may be found to represent the future organism or at least the component parts or "unit characters" of which the bodies of plants and animals are supposed to be built.

Naegeli found reasons for believing that organic characters must be transmitted by solid particles rather than by liquids or solutions, and the idea of material determinants has been greatly elaborated by Weismann and his followers. But none of the corpuscular theories thus far proposed can be said to convey an adequate conception of the processes of heredity. Characters can be thought of in other ways more consistent with the facts of heredity.

Many of these speculations regarding the internal mechanism of heredity are interesting, but it has yet to be shown that any basis of fact has been secured or that they have been of real assistance in recognizing or interpreting the external phenomena. The science of heredity is still in the first stage of development. Primary questions regarding the normal conditions and manifestations of heredity are still to be answered. Some of the most general and fundamental facts in organic nature, such as the organization of plants and animals into species, and the individual diversity everywhere found among the members of normal species, are left out of account in current theories of heredity and breeding. Though it is hardly possible to understand the nature of heredity without recognizing the conditions of its normal manifestation, this phase of the subject usually receives little or no attention in our educational institutions. Very few students become familiar with the facts of diversity in natural species or even have the need of such familiarity brought to their attention.

Failure to recognize diversity and free interbreeding among the members of species as normal conditions of organic existence has made it possible to look upon uniform, unchanging "pure lines" of descent as examples of normal heredity. But uniform expression of characters is not the form of heredity shown in natural species where free interbreeding forms a connected fabric of interwoven lines of descent. Such interbreeding maintains the vigor and fertility of the group, but these qualities are lost when descent is restricted to narrow strains or individual lines. The vigor secured by the crossing of different lines of descent ought to be recognized and utilized as a normal factor in the physiology of reproduction, instead of being looked upon as something exceptional and monstrous, like the abnormal phenomena of hybridization. Biological evidence indicates that the general application of pure-line theories to plants and animals, or to mankind, would not bring permanent strength or improvement, but would lead ultimately to weakness and extinction.

The individual diversity of mankind, the most familiar fact of heredity, may be taken as an example of the normal condition of expression of characters in freely interbreeding wild species. To accept uniform expression of characters as the normal state of heredity would amount in the human species to the acceptance of identical twins as typical examples of human inheritance. The usual object of breeding superior varieties of domesticated plants and animals is to produce larger numbers of individuals with the same set of characters, but this is not assisted by assuming that uniform expression of characters is a normal condition of heredity. If uniformity were the normal condition a selected "pure strain" might be expected to remain uniform, but in reality selection must be maintained or the variety will "run out" by returning to the original condition of diversity.

MATERIALS OF HEREDITY AFFORDED BY THE COTTON PLANT.

The cotton plant affords unusual opportunities for the investigation of problems of heredity. The large size of nearly all the parts greatly facilitates the study of characters and the recognition of variations. The period of flowering is not limited to a few days, but often continues for three months or longer, through the whole period of crop development, so that all of the adult characters can be studied on the same plants at the same time.

The length of the flowering and fruiting season allows the effects of changes of external conditions to become apparent in the different parts of the same plant. Thus, it is possible to learn the extent of the changes that can be brought about, even in the adult plants, by differences of temperature and humidity while the plants remain in the same soil.

The cotton plant has several highly specialized characters that are unusually susceptible of changes in definite ways, whether from genetic or environmental causes. The most specialized features are the two types of branches, different in structure, function, and form of leaves; the double involucre, with two forms of bracts; and the fibrous covering of the seed, with the two types of hairs. The specialized characters are not only more susceptible to the influence of external conditions, but are also most frequently affected by other kinds of variation.[1]

The cotton plant also furnishes an unusual wealth of materials in the way of distinct varietal and specific types. No other genus of crop plants contains so many domesticated species, to say nothing of the endless varietal forms to be found in all cotton-growing countries. While the different types are being compared and tested for cultural and breeding purposes there are ample opportunities for the study of parallel variations and reversions to ancestral characters and of the relation of such variations to differences of external conditions.

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[1] Several of the specialized characters of the cotton plant have been described in previous publications of the Bureau of Plant Industry, U. S. Dept. of Agriculture: Bulletin 88, Weevil-Resisting Adaptations of the Cotton Plant, 1906. Bulletin 198, Dimorphic Branches in Tropical Crop Plants: Cotton, Coffee, Cacao, The Central American Rubber Tree, and the Banana, 1911. Bulletin 221, Dimorphic Leaves of Cotton and Allied Plants in Relation to Heredity, 1911. Bulletin 222, Arrangement of Parts in the Cotton Plant, 1911. Bulletin 249, The Branching Habits of Egyptian Cotton, 1912.

In addition to the several distinct species and numerous varieties of cotton in regular commercial cultivation, many unimproved types are scattered through the tropical regions of both hemispheres. Some are in the hands of primitive tropical tribes, while others are still in the wild state. Such materials are needed for the study of heredity, in order to complete the series between normally diverse, unselected species and uniform, line-bred strains, like those that usually figure in laboratory and garden investigations.[1]

Without such comparisons between the behavior of characters in different groups, and the reactions of the same groups to different environments and states of breeding, it is very difficult to learn the expression relations of the different characters or to appreciate the larger relations between heredity and evolution. In the absence of a distinction between uniform pure lines and diverse natural species, any definite change in the expression of a character is likely to be mistaken for an evolutionary development of a new character or a new species, as assumed in the theory of mutation.

The study of cotton, as of many other plants, leaves no doubt that abrupt mutative changes of characters take place and that such changes are often permanent. Some mutations are superior to the parental stocks and are useful as parents of improved strains. Other mutations, and by far the larger number, are inferior and serve to destroy the uniformity of select strains unless recognized and removed. The preservation of uniformity in superior varieties of cotton is only to be accomplished by a vigilant roguing out of inferior mutations.

The same general range of diversity has been found among the members of unselected types of cotton as among the degenerate variations, "sports" or "mutations," that continue to appear in the most uniform strains that have been developed by selection. In the breeding of cotton for weevil resistance and other new requirements it has been necessary to take account of the diversified characteristics of wild species and unimproved stocks that have never been reduced to uniformity by methodical selection.

The fact of mutative change does not prove that the characters of mutations are new or that they represent progressive steps in the evolution of natural species. The wild and unimproved types of cotton are not separated from each other by definite unit-character differences like those that distinguish the mutative variations that appear in otherwise uniform, select strains. That mutations do not represent new species is no reason for disregarding their existence, nor for failure to recognize their practical importance.

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[1] In nature, among open-pollinated (allogamous) plants (and presumably among a great many animals) there is no such thing as a "pure" species which will breed true in all its characters, showing only purely fluctuating variability. It is only by selecting and inbreeding for a few generations that we get "pure lines." The only pure lines in nature are to be found among strictly self-fertilized (autogamous) forms. (See Gates, R. R., "Mutation in Oenothera," American Naturalist, vol. 45, 1911, p. 578.

The methods that have been applied to the study of the cotton plant have been developed through a previous familiarity with similar facts of natural diversity, mutative variation, and definite specialization of vegetative parts in coffee and other crop plants of tropical origin belonging to several different families. Members of many wild species of plants and animals, natives of widely different conditions, tropical and temperate, humid and dry, have been compared and found to represent the same primary condition of individual diversity. Even the wild wheat plant recently discovered by Aaronsohn[1] in Palestine has proved to be a normally diverse interbreeding species, in complete contrast with the uniform self-fertilized strains of domesticated cereals that have figured so largely as the basis of general conclusions regarding the nature of heredity and the principles of breeding.

HEREDITY IN NATURAL SPECIES.

Interpretations that seem to accord very well with one group of facts appear entirely inadequate when put to the test of more general application. Many theories of heredity and evolution deduced from laboratory experiments are fundamentally at variance with conceptions formed by naturalists familiar with species in nature. Natural species seldom show definite character-unit differences like the mutative variations that have been supposed to represent the origination of new characters and new species under experimental conditions. Laboratory experimenters seldom take into account the constitution of natural species. In like manner field naturalists often disregard facts that have been demonstrated by laboratory experiments, being unable to accept theories that have been deduced from such facts.

The present limited views must give place to a conception broad enough to include the facts of heredity shown in large natural groups as well as those ascertained by formal experiments with select individuals or strains. The apparent conflict only shows the need of studying the subject from other standpoints, with no misleading insistence upon one particular kind of facts to the exclusion of other kinds. Nature is a vast experiment where improved methods of reproduction and inheritance of characters are being worked out in the evolution of millions of different species. Evidence is readily had on almost any point, if we only know where to look for it. The conditions of evolutionary progress in nature must be recognized and accepted as a general basis or background for the interpretation of special groups of facts secured by special methods of breeding.

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[1] Aaronsohn, A. Agricultural and Botanical Explorations in Palestine. Bulletin 180, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1910, pp. 42–45. In addition to the facts of diversity reported by Aaronsohn, direct evidence of interbreeding was found during a visit to Palestine in the summer of 1910. (See Report of the Acting Chief of the Bureau of Plant Industry for 1910, p. 24.)

The idea of heredity as a process of segregation or separate transmission of character units derived from different parents does not comport with the general facts of evolution. Species differ from each other and their members differ among themselves in ways that are not recognized from the laboratory point of view. The development of new characters and organs requires the combination and integration of many variations, as provided by the association of plants and animals into specific groups of freely interbreeding individuals. Mutative variations of select stocks should not be confused with the gradual development of new characters in natural species.

Some writers have considered evolution as a process of isolation and segregation of characters, but cases supposed to represent the origination of new species in this way can be better understood as examples of abnormal variations or reversions. With the facts of heredity limited to a few animals and plants bred in cages and gardens, it is possible to entertain the conception that new species arise by sudden changes of unit characters, but those who are familiar with natural species know that they are very differently constituted. An adequate conception of heredity must recognize the conditions of inheritance among the freely interbreeding lines of descent in natural species as well as the conditions found in selected varieties where the natural network of descent has split into narrow strands or individual lines.[1]

The individual plant or animal represents one of the junctions or knots of the network of descent. Vast numbers of lines of descent pass through each joint of the network, lines that converge from all the ancestors and diverge to all the descendants. The fact that organisms lose their vigor and fertility when removed from the network of descent by being propagated in separate lines, but show renewed vitality when the separated lines are reunited, makes it evident that the weaving of the lines together to form a network of descent has a physiological value. Reproduction in a broad network of descent maintains the vigor and fertility of species, while reproduction in single or narrow lines sustains vitality for only limited periods.

Many kinds of plants and animals can be propagated in simple or narrow lines of descent for a series of generations, but there is nothing to indicate that any method of line breeding will permanently maintain the vitality of a stock. If propagation takes place by self-fertilization or some other form of line breeding, uniform expression of characters may become established in natural species, the same as in pure lines that are artificially bred, though in nature such lines are only temporarily separated from the network of descent of the species. The normal evolutionary species is represented by the network of diverse interbreeding lines, not by the uniform self-fertilized lines. Self-fertilization, parthenogenesis, and vegetative propagation are to be considered as supplementing sexual reproduction, not as adequate substitutes for natural crossing of the lines of descent.

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[1] Cook, O. F. Methods and Causes of Evolution. Bulletin 136, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1908. See also "The Superiority of Line Breeding over Narrow Breeding," Bulletin 146, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1909.

The relation of the network of descent of the species to the maintenance of vigor and fertility has become easier to understand in the light of recent discoveries regarding the nature of the cells that compose the bodies of the higher plants and animals. There is a profound difference in this respect between the higher types of organisms and some of the lower groups. The nuclear elements of the cells that compose the bodies of the higher types are double, so that each cell corresponds to two cells in the lower types. This peculiar condition of double cells arises from a difference in the process of conjugation. In the lower groups conjugation is completed in a comparatively brief period of the life history, while in the higher groups the cells remain in the double, conjugating condition during a very large part of the life history, so that it is possible to build up large bodies composed entirely of double cells, representing a state of prolonged conjugation of the original gametes.[1]

SPECIES AS PHYSIOLOGICAL ORGANIZATIONS.

In attempting to understand the structure of protoplasm as a mechanism of descent, the structure of the species as a network of descent has been left out of account. Though the association of organisms into species does not serve structural or economic purposes directly, it has the physiological function of maintaining vigor and fertility. From the physiological standpoint it is just as necessary to recognize the existence of the network of descent of the species with normal diversity and free interbreeding, as to understand the cellular and protoplasmic structure of the bodies of individual plants and animals.

That the individual plant or animal represents a social organization of the various kinds of cells that compose the body is a familiar idea among students of structural biology. Moreover, the individual cells are connected into a network by narrow strands of protoplasm that perforate the walls. Even the protoplasm itself is now known to have a reticular or netlike structure.

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[1] Cook, O. F., and Swingle, Walter T. Evolution of Cellular Structures. Bulletin 81, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1905.

More complex types of structural units are found in the segments of animals and the internodes of plants. This is most obvious in cases where the numerous metamers or joints that make up the body are also capable of an independent existence. The different kinds of internode metamers that compose the bodies of plants may be compared also with the several different kinds of specialized individuals found in colonies of social insects—bees, ants, and termites. Though many groups of plants and animals have the power of vegetative or asexual reproduction, none of them have been able to dispense with sexual reproduction. For many agricultural purposes vegetative propagation is superior to sexual reproduction, but vigor and fertility are not permanently maintained.

The specific constitution or speciety of living matter, the association of all plants and animals into normally interbreeding specific groups, should be considered as one of the distinctive biological properties or necessary conditions of the continued existence of complex organisms. The perpetuation of all the higher types of plant and animal life seems to be as truly dependent upon the fact that organisms are always associated in species as upon other properties of protoplasm that are usually recognized, such as irritability, assimilation, growth, and reproduction.

In the study of heredity and breeding, primary consideration should be given to the constitution of natural species as networks of interweaving lines of descent rather than to the formal taxonomic idea that species are based on "identity of form and structure," as a dictionary definition states. The identity sought for by the systematist is in reality merely an agreement in a few formal characters that most readily serve the taxonomic purpose of distinguishing the members of one species from those of another.

This formal taxonomic view of species has often misled evolutionists as well as students of heredity. The subdivision of large species into smaller and more uniform groups does not represent the typical condition of evolutionary progress any more than uniform groups represent the typical condition of heredity. Evolutionary progress is represented by changes of characters in large species rather than by the isolation of numerous small species. Heredity, no less than evolution, is a group phenomenon. The specific network of descent rather than the individual line is the fundamental fact of heredity, as of evolution. Not to know the constitution of the species is not to understand the constitution of the germ cell, for the one depends on the other.

The differences found among the members of one large species are often greater than those that serve to separate smaller or more uniform species. The diversity of large species is the most favorable condition for evolutionary progress, as Darwin recognized, and also represents the typical condition of heredity and breeding. The diversity found in the human species, for example, is more normal than the uniformity of "pure strains" of domesticated plants and animals. The development of a uniform "pure strain" of a domesticated plant or animal is an agricultural improvement when it enables the yield or the commercial value of the product to be increased, but no one who appreciates the biological nature of such strains would propose to use the same methods for the improvement of the human species.

Many of the variations selected as improvements of plants and animals for economic purposes represent negative changes or suppressions of characters. Instead of the total equipment or content of transmission being increased by constructive additions of new characters or functions, the expression of some of the characters is reduced or omitted altogether. It is a mistake to confuse the results of individual selection with the evolution of species through progressive changes of characters under natural conditions of free interbreeding.[1]

Selection regulates the expression of characters by restricting descent to particular lines that show the desired characters or degrees of expression, but there is no reason to believe that new characters not already present in the ancestry of the group can be brought into existence by selection. The most carefully selected types of Upland cotton do not have larger bolls or longer lint than are found in some of the native Central American stocks of Upland cotton that have not been subjected to conscious selection.

TRANSMISSION DISTINCT FROM EXPRESSION.

Two distinct processes are involved in heredity. The transmission of characters is independent of expression. If transmission and expression were the same, the transmission of a character would necessarily involve expression. All the characters would be shown in all the individuals that are able to transmit them. In reality a large part of the characters are transmitted without being brought into expression. They may remain for many generations in a dormant or latent condition. The full series of transmitted characters might be compared to the stock carried by a merchant, while those that are brought into expression would represent the small assortment placed in the show window.

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[1] "The pure line, while a valuable and necessary means of analyzing various problems of heredity, is essentially a laboratory product seldom duplicated in nature among allogamous plants. By continued inbreeding and selection to smaller and smaller differences, races which are more and more uniform may be obtained, as the 'pure-line' work tends to show. But the natural wild species must (unless regularly self-fertilizing) be looked upon as an intercrossing population of races whose appearance is ever changing (within limits) from generation to generation, according to the particular series of crosses or 'selfings' which happen to occur in each generation. Some of the races are likely to fluctuate in numbers or be dropped out entirely as conditions change." (See Gates, R. R., "Mutation in Oenothera," American Naturalist, vol. 45, 1911, p. 578.)

The failure of a character to come into expression is not the same as a failure of transmission, for the character may reappear in later generations. Though all the lines of descent share the same general equipment or content of transmission, each individual is necessarily limited to the expression of a single set of characters. Transmission may be considered as a permanent, invariable factor or common denominator of heredity; expression as a small and highly variable numerator of the individual fraction.[1]

In this conception of a germ cell as a transmitter of all the ancestral characters modern science affords a curious parallel with the ancient allegory of Pandora, the All-Gifted, the woman who received all the good and evil gifts of the gods for mankind. Pandora was blamed for letting the gifts of the evil deities escape into the world, while those of the good deities were left imprisoned. Bringing the wrong characters into expression may still be considered as the chief impediment of human progress. Pandora was married to Reflection, the brother of Progress. The Greeks were in advance of us in appreciating the importance not only of eugenics but of what might be called "euphanics," or the art of bringing desirable qualities into expression. They recognized the need of training the young by intimate contacts with all the activities of life, instead of limiting education to formal instruction in schools.

The breeder, no less than the educator, has to deal with expression of characters. The processes of transmission are still beyond our control, as well as outside our comprehension. The practical problems of heredity lie in the field of expression. The differences that exist among members of the same species, varieties, or strains, the differences that serve as the basis of selection and of all investigations of heredity and breeding, are differences of expression rather than differences of transmission. Selection is our means of avoiding the expression of undesirable characters, but there is no way to exclude them from transmission, except by destroying the whole stock. For constructive progress it is not enough to reject the obviously inferior individuals. Preference must be given not only to the best individuals, but to those that yield offspring without the undesirable characters. The chief problem of heredity is to understand the laws that control the expression of characters.

In a normally diverse wild type each individual shows a different set of characters, a fact most familiar in the human species. Identical twins illustrate the expression of the same set of characters in two individuals. Uniform, selected varieties or "pure strains" of domesticated plants and animals represent the expression of the same set of characters in large numbers of individuals, but the usual normal condition is a varied or alternative expression of different sets of characters. In the Mendelian theory of heredity, transmission is supposed to be limited to a single set of characters. Failure to distinguish clearly between transmission and expression is a frequent cause of confusion and ambiguity in the literature of heredity. Many writers identify heredity with transmission, as in the theory of Mendelism, while others use heredity in the sense of expression.[1]

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[1] Cook, O. F. Transmission Inheritance Distinct from Expression Inheritance. Science, n. s., vol. 25, June 7, 1907, p. 911.

Apart from this misleading assumption, the special study that has been given to Mendelism in the last decade has been of use in bringing alternative phenomena of heredity into greater prominence. Attention has been given almost exclusively to Mendelian forms of diversity, but other phenomena of alternative expression are of more general significance. The result of alternative expression of characters in natural species is to preserve variations and maintain diversity, even under conditions of free interbreeding. Recognition of this fact removes the ground for the former belief that variations could not be preserved and made effective for evolutionary progress unless they were isolated, because of the alleged "swamping effects of intercrossing." The older idea of the results of mixing different species or varieties was that the characters would finally blend or reduce to an intermediate average, but this no longer appears to be true. The distinctive characters of the parental types are not lost or permanently fused in the hybrids, but continue to be capable of full expression in later generations.

Though an intermediate expression of contrasted parental characters often occurs in the first-generation or conjugate hybrids, this is now recognized as a merely temporary condition. In the second-generation or perjugate hybrids the parental characters reappear in fully contrasted expression instead of being limited to intermediate or blended expression as in the first generation.

The theory of alternative transmission may appear adequate as long as the second generation shows nothing outside the range of the parental characters, but when a wider range of diversity is found, as usually happens in cotton hybrids and frequently in the hybrids of other plants, it becomes evident that crossing has done more than to form different combinations of the contrasted parental characters by alternative transmission. Another effect of crossing varieties is to arouse latent characters to expression and thus induce a return toward the normal diversity of the species.

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[1] "Our second purpose in this Harvey Lecture is to show that the evidence for continuity in the genesis of certain characters in man and other mammals is very strong indeed; further, that some of these characters, while apparently continuous in origin, certainly become discontinuous in heredity; from which it follows that discontinuity in heredity constitutes no proof of discontinuity in origin." (See Osborn, H. F., "The Continuous Origin of Certain Unit Characters as Observed by a Paleontologist," American Naturalist, vol. 46, 1912, p. 186.)

Any definite variation that has once occurred in a species is likely to reappear in undiminished form in at least a part of the offspring or their descendants. New variations do not need to be separated from the parent stock by selection or otherwise in order to escape the alleged "swamping" effect of dilution with the parent form. The principle of alternative expression provides for the development of new characters and functions by accumulation and integration of variations or, in other words, by building up advantageous relations of expression among the different alternative characters. The effect of selection is to regulate the expression of characters and establish the more advantageous combinations.

What there may be in the protoplasm of the cells to correspond to the external features of plants and animals and make possible an accurate transmission of such features from one generation to another is not known. Only the results of heredity are definitely known; the mechanism remains a matter of conjecture. The results afford some indications regarding the workings of the process, but these indications are in the nature of inferences, not direct observations. The characters have to be seen and thought of as external appearances, not as internal entities of the protoplasm. The study of heredity is based simply on observation and comparison of individual plants or animals to see whether they are alike or different; in other words, upon the expression of the characters.[1]

VARIATIONS AS CHANGES OF EXPRESSION.

Until the nature of the mechanism of heredity is understood no complete answer can be given to questions regarding the causes of variation. Experiments may prove that the expression of a character is modified by an external condition, but do not show how the internal processes of heredity are affected. For some purposes it is sufficient to say that a certain character is caused or induced by a certain condition, but there may be many untraced steps between the external condition or "cause" and the consequent variation.

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[1] "We know already that the experience of the breeder is in no way opposed to the facts of the histologist, but the point at which we shall unite will be found when it is possible to trace in the maturing germ an indication of some character afterwards recognizable in the resulting organism. Till then, in order to pursue directly the course of heredity and variation, it is evident that we must fall back on those tangible manifestations which are to be studied only by field observation and experimental breeding.

"The breeding pen is to us what the test tube is to the chemist—an instrument whereby we examine the nature of our organisms and determine empirically what for brevity I may call their genetic properties. As unorganized substances have their definite properties, so have the several species and varieties which form the materials of our experiments. Every attempt to determine these definite properties contributes immediately to the solution of that problem of problems, the physical constitution of a living organism." (See Bateson, W., "Heredity and Evolution," Popular Science Monthly, vol. 65, 1904, pp. 530–531.)

Many writers have laid emphasis on direct effects of environment as causes of variation. Plants may be kept small or rendered abnormal in other respects by having too little or too much water, heat, or light, or colors may be changed if the tissues are penetrated by chemicals or dyes. To keep a plant small may be considered as a direct effect of environment, but the reduction or suppression of a character is not to be confused with the substitution of a different character. That an external condition, such as temperature or humidity, enters directly into a cotton plant to change the form, texture, or hairy covering of the leaves is not to be assumed. The plant grows in a different way after the conditions are changed and brings different characters into expression.

Indirect, adaptive changes of characters in response to changes of external conditions have more significance in heredity than direct effects, because they represent activities of the plants instead of mere limitations imposed by environment. Still greater interest attaches to the more permanent changes of characters, the definite mutations or reversions that often take place without changes of environment and persist in different environments.

Many changes of expression occur regularly during the development of each plant, in producing the specialized forms of branches, leaves, and floral organs. These changes are also much greater than any induced by differences of external conditions. From the standpoint of heredity the development of each individual plant or animal should be looked upon as a process of changing characters quite as much as the development of the species. Variation in the sense of diversity of expression of characters is as normal for the species as the developmental changes are for the individual.

Many difficulties are introduced into the study of variation by failure to recognize the facts of diversity. With uniformity accepted as the normal condition, it seems logical to begin the study of heredity by seeking for the causes of changes of characters, as so many investigators have done. The nature of the problem is altered when it is perceived that diversity is the normal condition of species and that heredity provides in advance for a wide range of expression of characters. In a practical study of heredity the first object is not to learn causes of variation, which exists everywhere in the greatest abundance, but causes of uniformity, in order to establish and maintain the expression of desirable characters and avoid the expression of undesirable characters.

NEW-PLACE EFFECTS AND ACCLIMATIZATION.

The power of external conditions to induce profound alterations in the expression of characters could hardly be shown in a more striking manner than by the behavior of the foreign types of cotton when planted for the first time in the United States. The Kekchi type of Upland cotton, grown under native conditions in eastern Guatemala, is a small, compact, early, productive plant. Raised under Texas conditions it would not have been recognized as the same species of cotton if the origin of the seed had not been definitely known. The experiment was repeated many times with different stocks of imported seed. Many other varieties from Central America and Mexico have showed similar changes of behavior on being brought to the United States.

It is no exaggeration to say that the expression of all of the characters of the Kekchi cotton is changed under the new conditions.

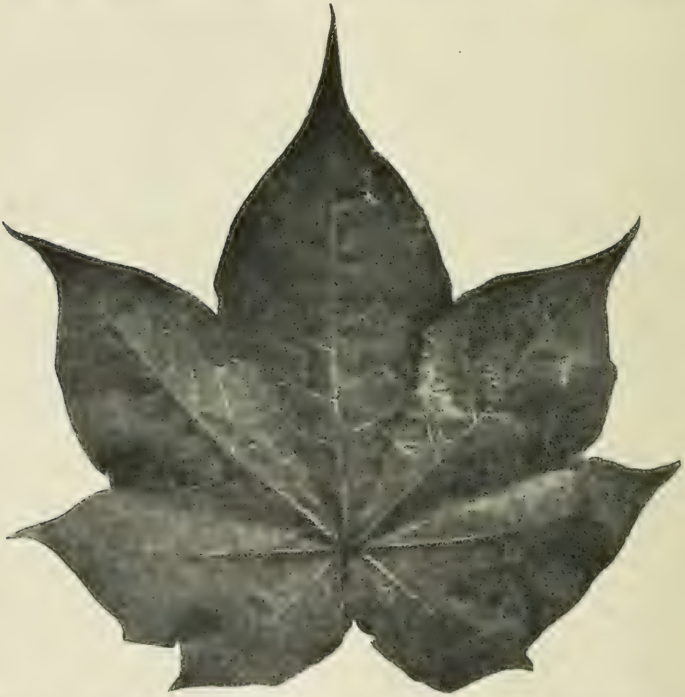

FIG. 1.—Leaf of unacclimatized plant of Kekchi cotton. (Natural size.)

Instead of producing a low, early, dwarf type of plant, as in Guatemala, the Kekchi cotton grows in Texas into a large leafy bush. Many of these huge, overgrown plants remain completely sterile throughout the season, but some of them produce a few small bolls. The changes in the shape and habits of the plants result from the fact that the fruiting branches of the normal plants are more or less completely replaced by vegetative branches.

In addition to these alterations in the habits of growth there are many changes in the form and texture of the leaves, the structure of the involucre, the number of carpels, and the length and abundance of the lint.

The leaves become larger, softer, and more hairy, with more numerous lobes, and have a closed sinus at the base. The extent of these changes may be judged by comparing figures 1 and 2, which represent leaves of the usual form on plants of Kekchi cotton before and after acclimatization. Both plants were grown under the same conditions at Bard, Cal., in the season of 1910. The involucres have more numerous and larger bractlets. The bolls, if any are produced, are much smaller than in Guatemala and have only three or four locks, very seldom five. The lint shortens from nearly an inch and a quarter to an inch or less and becomes very sparse. The fuzzy covering of the seeds may become abnormally developed or may show a greenish color.

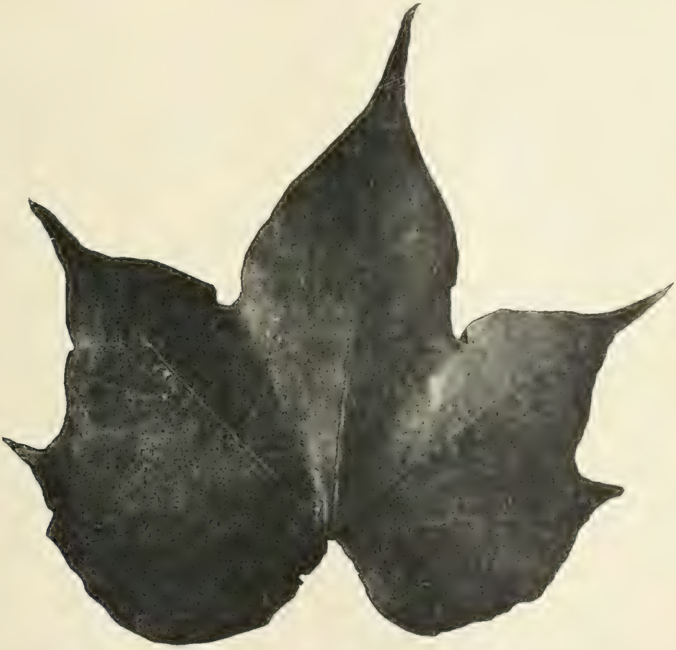

FIG. 2.—Leaf of acclimatized plant of Kekchi cotton. (Natural size.)

These changes are not permanent. They represent merely a temporary suppression of the normal characters, not a loss from transmission. In five or six generations the expression of the normal characters is reestablished, and the Kekchi cotton returns to its original condition of fertility. At the same time the bolls increase in size and the fiber shows a length and abundance equal to that of the best plants of the original Guatemalan stock. The 3-locked bolls that occur frequently on the large, infertile, unacclimatized plants are replaced by a normal proportion of 5-locked bolls.

Attention was first called to this difference in the number of locks by Mr. Rowland M. Meade, at San Antonio, Tex., in the season of

1908. Most of the plants grown from imported seed were completely sterile and the others bore only a few bolls. Of 41 plants with bolls, only 5 individuals produced any with 5 locks. In adjacent rows of partially acclimatized Kekchi cotton none of the plants were completely sterile, and the proportions of 5-locked bolls were much higher, as Table I will show.

TABLE I.—*Census of the bolls and locks of unacclimatized and partly acclimatized plants of Kekchi cotton at San Antonio, Tex., Sept. 12, 1908.*

Seasons.	Number of plants.	3-locked bolls.	4-locked bolls.	5-locked bolls.	Total number of bolls.	Average number of bolls.	Percentage of 5-locked bolls.
First	41	39	202	6	247	6	2.4
Third	12	9	215	30	254	21	11.8
Fourth	7	5	81	91	177	25	51.0

Similar results were obtained in the season of 1909 at Falfurrias, Tex., where adjacent first and second season plantings of the Kekchi cotton were compared, as shown in Table II.

TABLE II.—*Census of the carpels of bolls and late buds of 25 plants of first and second year rows of Kekchi cotton at Falfurrias, Tex., in 1909.*

Plant No.	First-year planting (from imported seed).						Second-year planting (from seed grown in Texas).					
	Bolls.			Buds.			Bolls.			Buds.		
	3-locked.	4-locked.	5-locked.	3-locked.	4-locked.	5-locked.	3-locked.	4-locked.	5-locked.	3-locked.	4-locked.	5-locked.
1										22	67	1
2				2	26	4		4			38	2
3				1						3	78	8
4										11	15	
5		1			2					2	68	1
6				3	3							
7				2	20					10	38	
8		6		1	5					4	43	3
9	2	8		9	9					4	69	
10				3	7			8	1	3	69	4
11										2	9	
12		5		4	24					2	1	
13	2	5		20	17			1			7	
14				4	1						1	
15										2	17	1
16		1			18		1	1				
17					1						4	
18					3					1	24	
19										5	50	6
20				7	21					9	47	2
21				11	10					8	51	6
22		2		4	39	2				4	30	2
23				3	8							
24				3	4		1			3	25	1
25	2	2		2				15		5	39	1
Total	6	30	0	79	218	6	2	29	1	100	790	38
Percentage	17	83	0	25.9	71.7	2.3	6.3	90.1	3.1	10.8	85.2	4.1

A more definite indication of the superior fertility of the second-year planting was afforded by the presence of numerous individuals that produced more numerous and larger bolls than any of the first-year plants. A count of the bolls of 10 such plants showed a total of 210, of which 2 were 3-locked, 190 4-locked, and 18 5-locked. The 10 fertile plants had less than 1 per cent of 3-locked bolls and 8.5 per cent of 5-locked bolls.

Other examples of variation in the proportion of 5-locked bolls were afforded by a series of plantings of acclimatized and unacclimatized Kekchi cotton in adjacent rows in several localities in California in the season of 1910. Localities with warmer climates produced lower percentages of 5-locked bolls, though the season of planting and the nature of the soil evidently affected the result in ways that other experiments have shown to be possible. Drought or other adverse conditions that reduce the crop also diminish the proportion of 5-locked bolls. In the hot interior valleys of California the proportion of 5-locked bolls in the unacclimatized stock fell nearly as low as in Texas. But in the acclimatized stock the proportion of 5-locked bolls often ran higher than in Texas. (See Table III.)

Table III.—*Census of bolls and locks of unacclimatized and acclimatized Kekchi cotton in 10 plantings in California (season of 1910).*

Localities.	Unacclimatized stock (from imported seed).					Acclimatized stock (raised for five seasons in Texas).				
	Number of plants.	3-locked bolls.	4-locked bolls.	5-locked bolls.	Percentage of 5-locked.	Number of plants.	3-locked bolls.	4-locked bolls.	5-locked bolls.	Percentage of 5-locked.
Red Bluff	19	3	137	34	19.5	20	3	322	256	44.1
Chico	20	6	304	43	12.2	23	4	175	275	60.6
Stockton	7	0	125	67	34.9	14	0	71	200	73.8
Visalia	25	16	325	115	25.2	3	0	8	7	46.6
Stockdale	17	3	150	105	40.7	19	0	96	[1] 444	82.2
Semitropic	16	61	451	21	3.9	16	2	96	377	79.4
Glendale	20	10	284	145	33.0	20	2	128	347	72.7
El Centro	19	40	77	4	3.3	...	...	...	...	...
Meloland	18	13	44	0	.0	20	5	219	121	35.1
Bard	20	181	523	23	3.2	10	7	653	730	52.5

[1] In this instance two 6-locked bolls were included with the 5-locked.

In hot climates, as in southern Texas and in the interior valley of California, adjacent rows planted with acclimatized and unacclimatized seed of the Kekchi cotton show striking contrasts in vegetative development and fertility. The unacclimatized plants grow to several times the size of the others and produce scarcely any cotton, while the acclimatized plants remain small and bear good crops (Pl. I, fig. 1). In the cool climate of Glendale, Cal., near the coast, the rows appeared much more alike (Pl. I, fig. 2), though the acclimatized stock had somewhat larger bolls and better lint, as though a simple selection had been used. The Kekchi cotton also behaves in a nearly normal manner in Kansas and in Maryland.

In acclimatizing a superior type of cotton we do not make the variety over by creating new characters, but merely bring back to normal expression characters that the variety is already known to possess. Success with this kind of acclimatization depends primarily on knowledge of the normal habits and characters, so that the variety may be guided back to normal behavior by the selection of the individuals and progenies that show most definite and regular expression of the normal characters.

As the variations induced by the new environments seem to extend quite outside the range of ordinary accommodations to external conditions, they have been described under a special name, "new-place effects." The acclimatization of such plants as cotton might be described as a process of avoiding or eliminating new-place effects. Though the new types of cotton have been brought from tropical countries, high temperatures seem to be the chief cause of abnormal behavior in the United States. The summer climate of the Southwestern States is much hotter than that of many tropical countries. Acclimatization might be said in this case to result in greater resistance to heat, for the processes of growth are no longer affected by the high temperatures that induce abnormal development in plants raised from newly imported seed.

PERSISTENT TRANSMISSION OF LATENT CHARACTERS.

The transmission of latent characters, though familiar to Darwin and many other investigators, is still treated by many writers as a special condition, as in Mendelian hybrids. In reality the latent or variable characters of a species are vastly more numerous than the characters that are expressed with regularity. Instead of being considered rare or exceptional, latency should be recognized as a universal, underlying fact of heredity. Taxonomists prefer to consider only the constant characters, those that are shown by all the members of the species, but the variable characters are significant in heredity and breeding. The same series of variations may run parallel through whole series of related species and genera without becoming established as uniform, taxonomic characters in any of them. Though there seem to be no limits to the transmission of ancestral variations, expression remains limited in each case to the relatively small set of characters that can be shown in a single individual.[1]

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[1] Though the formal distinction between transmission and expression seems not to have been drawn, many passages in the writings of Galton present contrasts between latent and patent characters, like the following example:

"From the well-known circumstance that an individual may transmit to his descendants ancestral qualities which he does not himself possess, we are assured that they could not have been altogether destroyed in him, but must have maintained their existence in a latent form. Therefore each individual may properly be conceived as consisting of two parts, one of which is latent and only known to us by its effects on his posterity, while the other is patent and constitutes the person manifest to our senses." (See Galton, Francis, "On Blood-Relationship," Proceedings, Royal Society of London, vol. 20, 1872, p. 394.)

The content or sum total of transmission is increased when new characters are added in the constructive evolutionary progress of a species, but there is no reason to assume that characters once developed ever cease to be transmitted. Evolutionary progress often involves the suppression of some of the more primitive characters, but the substratum of transmission remains; the pandoric equipment of the germ cells is not diminished. The development of each generation follows the path of all the preceding generations. The facts of reversion and recapitulation show that latent and rudimentary characters continue to be transmitted for hundreds and thousands of generations after normal expression has ceased. Socrates described the soul of man as "something sturdy and strong, imperishable by accident or wear," and so it may be said of transmitted characters, that they seem to have a permanent existence, preserved and passed down through unbroken lines of progency.

The persistent transmission of latent characters becomes all the more significant as an indication of the nature of heredity when it is considered that the suppression or reduced expression of characters is a very important factor of evolutionary progress. The addition of any new organ or function is likely to involve reductions or suppressions of other organs and functions, like the progressive reduction of teeth and other bones of the head in the more advanced, large-brained races of mankind. Viewed merely from the standpoint of characters as independent units such reduction may be confused with degeneration, but not when viewed from the standpoint of the species. An abnormal return of a reduced character to full expression is considered as a mark of degeneration, like the heavy jaws that are supposed to characterize certain classes of criminals.

The idea that the characters of adult organisms are represented by discrete particles or "units" in the protoplasm was developed by Darwin in the theory of pangenesis and elaborated by Weismann in his doctrine of the continuity of the germ plasm. In order to explain the inheritance of characters supposed to be acquired from the external environment, Darwin assumed that units or pangens representing the characters migrated into the germ cells from the various parts of the body. Weismann denied the reality of such supposed acquirements of characters from the environment, holding that the germ plasm is not affected by the vicissitudes of the parent organism.

The persistence of latent characters in transmission shows that the germ plasm carries not only the characters that are to be shown by the organism, but also the differences that are to appear among its descendants. In other words, continuity of transmission provides for variation, or discontinuity in expression. In view of the fact that nothing is known regarding the nature of transmission, there is no way to determine whether the characters are really represented by separate entities in the germ cells. The relations that govern the expression of the characters are of more immediate importance in the study of heredity.

The practical value of selective breeding as a means of regulating the expression of characters is quite independent of the idea that selection affects the transmission of characters. The influence of external conditions upon expression can also be recognized without supposing that new characters have been introduced into transmission. The influence of external conditions is not limited to the usual adaptive changes or accommodations, but sometimes serves to recall remote ancestral characters to expression. The new-place effects exhibited by the cotton plant may be considered as examples of reversions induced by changes of external conditions. The more extreme cases of new-place effects might be described as wholesale reversions to ancestral characters, all of the normal characters being suppressed.

REAPPEARANCE OF SUPPRESSED CHARACTERS.

The nature of the variations that continue to appear in selected strains can not be understood or the causes of such variations appreciated without taking into account the reserve stock of latent ancestral characters that can be recalled into expression. Selection serves to keep undesirable characters out of expression, but it does not put an end to the transmission of such characters or prevent their return to expression in later generations.

The rule that like parents produce like offspring represents only one phase or condition of heredity, partially attained after normal diversity has been suppressed by selection or line breeding. The production of like from like is the aim of the breeder, though he frequently finds that like produces unlike. The wider rule of nature is that unlike parents produce unlike offspring, not only through resemblance to the two parents, but through atavism, or reversion to more remote ancestors. Normal heredity should be considered as a group phenomenon. The diversities shown by ancestors and relatives are to be taken into account as well as the characters of select individuals or pure lines, if the full range of variation is to be learned.[1]

Without knowing the range of diversity of the natural group the full possibilities of improvement of a domesticated plant can not be judged. Extensions of agriculture into new regions and applications of plant products to new uses are continually calling for improvements along new lines. Characters previously disregarded in selection may become of primary importance and lend a corresponding interest to the varieties or species that are found to meet the new standard of desirability.

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[1] This idea has been stated very clearly by Davenport in the following paragraph:

"To define 'heredity' as the direct and personal relation between the individual parent and the individual offspring is not only to restrict its meaning within too narrow limits but to destroy its significance to the breeder and deceive him as to the actual facts of transmission during descent. 'Heredity' properly refers to the group that constitutes the parentage and the related group that constitutes the offspring." (See Davenport, E., "Principles of Breeding," p. 473.)

Valuable indications for further improvements of types already in use are often to be gained from the variations of related species, and especially from those that have not been reduced to uniformity by selection. Thus a recognition of the existence of weevil-resisting adaptations in stocks of Upland cotton cultivated by primitive Indian tribes in Guatemala and Mexico has opened the way to a study of weevil-resistant characters and cultural factors in the Upland varieties of the United States. After the more definite specializations of the Central American types of Upland cotton were known it was possible to recognize and appreciate the value of parallel series of variations that occur in our United States Upland varieties, though not previously recognized.[1]

That each of the lines of descent of a natural species can transmit the endless peculiarities of its highly diversified ancestry may be difficult to believe until the nature of the process of transmission can be understood, just as it is difficult for the average person to credit the idea of sending many simultaneous messages over the same wire. The only alternative to the acceptance of multiple transmission and variable expression is the assumption that all the mutative variations arising in selected stocks represent the reorigination of the diverse characteristics that the selection of pure lines is supposed to eliminate.

Though many of the facts of biology can be stated in physical terms, the best analogies of heredity are psychical rather than physical. Psychologists have long recognized the probability that the mind retains a permanent record of all the multitudes of impressions received from the senses. The retention of large numbers of impressions in the mind may be compared to the process of transmission, while the return of the different groups of impressions to consciousness is like the expression of characters in individual organisms. Though only a few of the impressions are capable of voluntary recall by the conscious memory, the subconscious record endures and is often revealed in unexpected flashes, analogous to the occasional return of remote ancestral characters to expression. To describe heredity as organic memory is not a mere figure of speech, for the mental faculties are a product of heredity, no less than the physical body.[2]

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[1] Weevil-Resisting Adaptations of the Cotton Plant. Bulletin 88, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1906.

[2] Cook, O. F. Heredity Related to Memory and Instinct. Monist, vol. 18, no. 3, 1908, pp. 363–387.

Heredity may be considered as an organic memory of the previous paths of descent, a memory that is transmitted because it inheres in the protoplasm of the germ cells. There is the same reason for holding that characters have a physical basis or representation in the protoplasm of germ cells as for supposing that impressions have a physical basis in the brain cells. That the mind is able to receive, retain, associate, and reproduce impressions and ideas is a fact even more familiar to us than heredity, yet of memory as a mechanical process we have as little conception as of heredity.

Neither of the logical alternatives so much discussed by the earlier investigators affords an adequate statement of the facts of heredity. There is as little advantage in assuming a definite preformation of each generation in the germ cells of the parents as in holding that reproduction involves an entirely new formation or epigenesis. If taken in sufficiently general senses, both doctrines are true. The forms of the ancestral generations are carried over to their descendants and yet each individual is formed anew after its own unique pattern.

The members of a species appear alike if compared with another species, but when compared more closely with each other they are found to be different. Such diversity is not a mere failure to hit the center of the target of ideal uniformity, but is a positive essential fact that must be taken into account in understanding the nature of heredity. The normal mechanism of heredity that maintains the existence of a species is not adjusted to produce a mere succession of identical individuals.

Though all the members of a species follow the same general course of development, they do not trace exactly the same courses. The fact of evolutionary progress shows that there is no absolute limitation to ancestral characters or combinations. The pathway of hereditary development in a natural species should not be thought of as a simple, narrow line, but as a broad track with many interlacing paths followed by different individuals. The individual differences are to be recognized, as well as the more distinct and widely separate alternatives of expression manifested in sexual specializations and other definite forms of diversity. In species that are divided into sexes or castes, two or more separate courses of development may be recognized. There are many different degrees of such specializations, as of other characters.

Instead of assuming in advance that heredity represents either preformation or epigenesis it is better to begin by recognizing that the course of development is not definitely fixed either before or after conjugation takes place. Many changes and alternatives of expression are possible. Each individual is different, though each is a part of the same network of descent. It is this conception of hereditary development as the following of a broad, well-beaten track or netlike pathway of development that should be substituted for the older assumptions. The controversies of biologists over preformation and epigenesis are closely analogous to those of anthropologists over monogenesis and polygenesis, the question whether mankind had a single or a multiple origin. Confusion arises in both cases from the failure to perceive the same fact—that evolutionary progress toward new characters is not a matter of single variations or of simple lines of descent, but is a change in a broad network of descent. In applying this distinction in anthropology the term "eurygenesis" was suggested as an alternative of monogenesis and polygenesis. Primitive men, like their present representatives, may be supposed to have constituted a large diverse group rather than a small uniform group or a series of entirely independent groups.[1]

If the mechanical conception of heredity as something in the nature of a system of invisible models, patterns, or determinant particles is to be retained, it must be vastly expanded to include all the different variations or alternatives of expression that are found among the members of normally diverse, freely interbreeding species. Other methods of reproduction, by restricted descent, enable the manifestations of heredity to be narrowed down to conditions of uniformity and definitely contrasted characters which can be interpreted by a simple theory of alternative transmission of character units, but to give exclusive consideration to these specialized states of uniformity is not to solve the underlying problem of normal diverse heredity, but rather to avoid it. It is much easier, of course, to trace the behavior of aberrant characters or lines of descent, those that wander away from the pathway of normal development or are artificially separated from it. This explains why so much more attention has been given to uniform line-bred groups than to diverse groups interbreeding in a normal network of descent.

The problem of heredity is not merely to provide for the formation of the small number of external differences commonly referred to as characters, but for the formation, specialization, and coordination of the almost infinite number and variety of cells that compose the tissues and organs of the bodies of plants and animals. And when it is remembered that each cell must be supposed to bear the determinants for reproducing all the other cells, the mechanical theory becomes a maze of inconceivable complexity. It is true that most of the cells of the higher animals are so specialized that they no longer serve purposes of reproduction, but with plants a large proportion of the cells retain the power of producing all the other kinds of cells. Cases where the leaves as well as the stems are able to produce new individuals by budding have been looked upon as examples of reproductive specialization, but should be considered rather as representing incomplete vegetative specialization.[1]

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[1] Cook, O. F. Kinetic Evolution in Man. Science, n. s., vol. 15, June 13, 1902, p. 927.

The germ cells must be supposed to carry the determinants, not merely of a few general, external features, but of all the internal organs and of the multitudes of cells that are to compose the bodies of their varied posterity. Every external character of a plant like cotton is a collective result of coordinated activities of vast numbers of cell individuals, each highly complex in itself. There is no more need of specialized determinants for the distinctive features of a variety than for the features that are not peculiar to the variety.[2]

It may be that the predication of determinant character units brings biology into more logical accord with corpuscular theories of physics, but this is not so important as to have biological theories accord with biological facts. Only a few of the characters of plants and animals appear to have definite reactions like those that physical chemists explain by their theories regarding the structure of molecules.

To compare organisms with crystals is a very inadequate analogy, but it is at least better than the analogy of amorphous compounds. Because the crystals of a certain substance are always of the same general form it is not held that they are controlled by special particles or determinants. To say that the substance has a property of crystallization does not explain how the crystals are formed, but it at least avoids the need of making a more complex and improbable assumption that there are special particles to control the different angles and planes of crystallization. The same substance may crystallize in a different system when placed under different conditions, but this does not compel us to suppose that new characters have been added. There are regular systems of leaf arrangement in plants even more complicated mathematically than the systems of crystallization in chemicals, but phyllotaxy is subject to variation like other characters of plants.

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[1] In addition to the usually cited illustrations of this condition in Bryophyllum and Begonia, another example was noted by Hance in 1849 in a Chinese plant, *Chirita sinensis,* of the family Gesneraceæ. In this case, as in Begonia, the young plants "sprang indiscriminately from the costa, primary veins, and connecting parenchyma." Hance also refers to reports of the same phenomenon in Ornithogalum and Drosera, members of two other widely separated families. (See Hance, H. F., "On Some Chinese Plants," Hooker's Journal of Botany and Kew Garden Miscellany, vol. 1, p. 141, pl. 5, fig. c.)

[2] That the Mendelian theory of alternative inheritance may not apply to the more fundamental characters has been recognized in the following passage:

"Aside from these cases which show a distinctly non-Mendelian mode of inheritance, it must be remembered that Mendelian analysis can be made only in the presence of differential unit characters possessed by individuals capable of life and of sexual reproduction, and that therefore there can be no test, except under rare circumstances, of the Mendelian nature of the more fundamental vital characters. This leaves it an open question whether the whole of the germ plasm is a complex of such genes as those which give rise to the phenomena of unit characters, or whether, with its wonderful general powers of assimilation, growth, and reproduction, it consists of a great nucleus of which the genes are relatively superficial structural characteristics." (See Shull, G. H., "Germinal Analysis through Hybridization," American Philosophical Society, vol. 49, 1910, p. 290.)

Regularity of expression, whether of frequency or of degree, affords no reasons, either logical or biological, for supposing that the characters of organisms are determined by preformed models or by discrete particles representing different characters. The doctrine of determinants could be applied with more reason to the expression of characters than to transmission. External conditions and internal secretions are already known to act as determinants of expression. That germ cells might be charged in advance with such determinants of expression is quite conceivable, and this supposition would accommodate all the facts that have been used to support the theory of alternative transmission. A convenient division of labor might be arranged on this basis, the undifferentiated protoplasm being considered as the seat of transmission of all the characters, and the chromosomes as determinants of expression, with specialized chromosomes to represent the definitely alternative characters.

FACTORS THAT CONTROL EXPRESSION RELATIONS.

Whatever the future may bring in the way of discoveries regarding the nature of transmission and expression, it is desirable to avoid further confusion of the two processes. Variations of plants or animals of the same species recently descended from common ancestors represent differences in the expression of the characters rather than differences of transmission.

The processes of expression evidently do not operate independently for each character, but have mutual interrelations, often very complex. The expression of one character may depend upon or conflict with the expression of other characters. In order to secure and maintain the highest degree of expression of desirable characters it is necessary to understand their expression relations. Unless these relations are taken into account the breeder may waste his time in vain attempts to establish the expression of incongruous and unstable combinations of characters. The study of heredity, as far as it is concerned with actual variations of plants and animals, is the study of expression relations. The control of expression relations is the art of breeding.

Potency is the name applied to inherited tendencies of expression. It is not sufficient to define potency as the power of transmitting characters, for the power of simple transmission of characters is a general property of organisms. Potency involves not merely the transmission of a character, but also the inheritance of a condition or factor of expression, something that brings about a strong and regular expression of the character in each generation instead of a weak, irregular, or intermittent expression.

Something more is required for expression than for transmission alone. There must be favorable conditions, internal and external, for each particular character, if full expression is to be gained. Though the mechanism of expression, like the mechanism of transmission, is still unknown, it is evident that external conditions, methods of breeding, and relations with other characters are factors that affect the mechanism of expression, though having no corresponding influence over the mechanism of transmission.

Though some changes of expression relations evidently arise inside the germ cell, others are induced by external conditions. It is safer, for scientific progress, to begin by considering the changes that can be influenced by external conditions or by breeding, and to use these as a basis for understanding the internal relations and the nature of the mechanism of expression. To proceed otherwise, by drawing out series of logical deductions regarding processes that are not open to direct observation, is to disregard the possibility of securing more practical points of view.

Even if it could be shown that certain characters have their residence in certain particles of the protoplasm the problem of controlling the expression of the characters would remain. In all probability it would still be necessary to deal with the characters through the external methods of influencing expression, rather than by manipulating the determinant particles inside the germ cell.

The most effective methods of selection are those that take into account the potencies of the characters. Instead of selection being based merely on the degree of expression attained in the individual parent, it should be based on regularity of expression in the progeny, as is most definitely recognized in the centgener methods applied by Hays to the breeding of wheat. A higher degree of expression may be attained in a few individuals or may result from some unusually favorable external condition, but without establishing a definite potency in the stock. Selection of the lines of descent having the largest and most stable expression of a desired character serves to establish and stabilize such expression, though mutative reversions and degenerate individuals continue to appear.

The effect of selection to increase the yield of a crop is explained by the greater uniformity secured by the rejection of inferior individuals. Yet selection alone can not be relied upon to maintain the largest possible yields. This has been demonstrated in many cases where conjugate hybrids of two strains have been found to produce much larger and better crops than either of the parent varieties grown under the same conditions. Increased vigor secured by crossing has the same practical advantage in improving the crop as planting in a richer soil or using more fertilizer. The superior vigor and fertility of the hybrids depend largely on their greater powers of resistance to unfavorable conditions.

CORRELATION AND COHERENCE IN EXPRESSION.

The value of correlation as a guide to selection has been recognized, and attempts have been made to discover useful correlations by elaborate systems of measurements. Regard for the distinction between expression and transmission makes it possible to place the study of correlation on a broader biological basis. Many so-called correlations, such as correlations between size and weight or between length of internodes and total height of plant, represent merely different mathematical statements of the same fact and have very little biological significance.

Biological correlations are to be interpreted in the light of the general fact of coherence of characters in hybrids, the tendency of characters derived from the same ancestral group to remain associated in expression. Characters that remain coherent in hybrids between different species are likely to be correlated in variations of unhybridized stocks. In other words, phylogeny may explain coherence and correlation.

Lack of coherence allows free combinations between the characters of the two parents, according to the laws of chance. This represents the typical form of heredity from the standpoint of the Mendelian theory, but other relations seem to be more common and more important in breeding. The expression relations of the characters in wild or unimproved allies of domesticated species often afford the best clues for the solution of breeding problems that depend upon coherence or correlation.

One of the limitations of the Mendelian theory of heredity is that it is based so largely on the idea of pairs of contrasted characters supposed to be separately transmitted, as in sexual differences. In less specialized kinds of characters, expression has not merely two alternatives, but many possible variations or degrees of expression. Only a few characters have the definitely contrasted polarity of expression of the typical cases of Mendelism. Even among characters that segregate in the later generations in a definite Mendelian manner only a few show either of the parental alternatives of expression in the first or conjugate generation of hybrids. In the great majority of cases the first generation shows different degrees of blended or graded intermediate expressions of the parental characters, or even characters that did not appear in the parents. Thus, when a variety of cotton with naked seeds is crossed with a variety having white fuzz on the seeds the hybrids are likely to have green fuzzy seeds.[1]

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[1] Cook, O. F. Reappearance of a Primitive Character in Cotton Hybrids. Circular 18, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1908.

All the facts of Mendelism seem to accord quite as well with the idea of alternative expression as with that of alternative transmission. The more careful investigators of Mendelism are beginning to recognize that only a relative "purity of germ cells," instead of an absolute purity, can be claimed. Occasional variations are found even in characters that have shown the typical Mendelian behavior in large numbers of cases.

Interesting examples of reversion and variable expression of the starch character in sweet corn have been reported recently by East and Hayes. Two explanations are suggested, either that the hypothetical character units, or "genes," are broken up into fractions, some of which remain in the recessive strains, or that the starchy character has reappeared as a result of new variation. The idea of frequent origination of the same character receives more favorable consideration, as the following statement will show:

> Either homozygous recessives (and likewise dominants) are not complete segregates, but products of a partial quantitative separation of genes allowing traces of the dominant character to remain, traces which may sometimes accumulate sufficiently to bring out the dominant character; or, progressive variations are constantly taking place in small numbers, most often along paths that have been passed before.
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> It is our opinion that dominant starchiness—if it is the same dominant starchiness—has been formed anew. It occurs too rarely to support a partial segregation theory, such as Morgan's. If it is asked why starchiness is the character that arises anew rather than another variation, it is suggested that the peculiar chemical structure of the germ cell of maize may be such that a molecular readjustment is much more likely to bring about starchiness than any other variation. Such a path of least resistance for variations might account for the many cases in animals and plants where the same variation has apparently occurred again and again.[1]

With latency and alternative expression of characters recognized as general conditions of heredity, it becomes unnecessary to resort to theories of alternative transmission, incomplete segregation, or frequent reorigination of characters. If the character units can be broken up into fractions and transmitted in different quantities or regenerated after having been removed completely from the stock, their nature must be very different from what was formerly assumed in the theory of pure germ cells. Such modifications amount to a practical abandonment of the definite features that have hitherto served to recommend the idea of alternative transmission. If each of the starchy variations of sweet corn is to be considered as an origination of a new character, the same reasoning should be applicable to any other character, such as color blindiness, that does not appear in the immediate parents.

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[1] East, E. M., and Hayes, H. K. Inheritance in Maize. Bulletin 167, Connecticut Agricultural Experiment Station, 1911, pp. 42–43.

Greater permanence can be ascribed to the underlying mechanism of heredity when the distinction between transmission and expression is recognized, and there is less need of insisting upon discrete units to represent the different characters. Whatever the nature of the mechanism that transmits the characters, it need not be supposed to change because the factors of expression are altered. Many different fabrics can be woven on the same loom by merely changing the patterns. The differences shown in the same stock of plants or animals represent different patterns of expression, all based on the same equipment of transmitted characters.

Even in cases where sex has been found to be determined in advance by the presence or absence of an accessory chromosome in one of the parent germ cells, it is hardly to be held that the sexual characters themselves are directly represented by this chromosome any more than by the heat, sunlight, or other external conditions and internal secretions that have been found to influence the expression of sexual characters in other cases. Increase in the proportion of males in hybrid stocks over the proportions shown in the parent varieties also indicates that the determination of sex depends upon other factors than simple alternative transmission of the sexual characters.[1]

The fact that males are produced from unfertilized eggs of bees and other hymenopterous insects does not warrant the inference drawn by some writers that the female characters are not transmitted by the female sex. Indeed, it is now known that female insects as well as male sometimes develop from unfertilized eggs. Sexual differences, like contrasted Mendelian characters, may be looked upon as examples of alternative expression instead of alternative transmission. Peculiarities of one sex are transmitted by the opposite sex as well as by the same sex and may even be brought to expression, as in an abnormal hen that grows long tail feathers and crows, or in a caponized male that hovers chickens. The specialization of sexual characters has gone on independently in so many different groups of plants and animals that the same relations of expression are not to be expected in all cases. To generalize on sexuality as a Mendelian character is to substitute the same abstract term for a widely varied series of biological facts.

Dimorphic forms of leaves and branches in plants are analogous to the sexes and castes of animals. Each plant may be considered as a colony composed of several different kinds of internode individuals, often capable of an independent existence. The different kinds of internodes show alternative or contrasted expression of characters, like Mendelian or sexual differences. After several of the lower internodes of a cotton plant have produced vegetative branches there is an abrupt change to a different type of branches, those that bear the flowers and fruit. There can be no question that dimorphic differences represent changes of expression rather than changes of transmission, for the contrasted characters are shown among the internode members of the same plant.

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[1] King, H. B. The Sex Ratio in Hybrid Rats. Biological Bulletin, vol. 21, July, 1911, p. 104.

In addition to the functional difference the fruiting branches of the cotton plant have other specializations, like the secondary sexual characters of animals. The leaves of the fruiting branches are usually somewhat different from those of the vegetative branches, and in Egyptian cotton the stipules of the two kinds of branches are quite distinct. The shortening of the internodes of the fruiting branches, as in the so-called "cluster" varieties of cotton, does not extend to the vegetative branches. Varieties of cotton that do not maintain the normal specializations of the different kinds of branches, leaves, and floral parts are undesirable. Abnormal fruiting branches usually produce abnormal leaves and involucres and frequently abort the buds or the bolls.

That the expression of one character often involves the suppression of another is true in the development of a race as well as in the growth of an individual, though it does not appear that the suppressed characters are excluded from transmission. Abrupt changes or contrasts of expression are evidently as natural as gradual changes and as little in need of being explained by theories of alternative transmission.

In the Mendelian system, the suppression of a character to a condition of latency has to be explained by the presence of another inhibiting unit. As Castle has recently shown, it is possible to make very complicated Mendelian problems out of facts that are capable of simple physiological explanations.[1]

THREE KINDS OF EXPRESSION RELATIONS.

In order to facilitate a more definite study and description of the relations of expression and to avoid the confusion introduced by theories of variable transmission, three principal types of such relations may be recognized. When the expression of one character depends upon or conduces to the expression of another character the relation may be called "symphanic." When the expression of one character inhibits or interferes with the expression of another the relation may be called "antiphanic." When the expression of one character neither favors nor interferes with the expression of another the relation may be called "paraphanic."

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[1] "Consider how one unproved hypothesis has been added to another. First, it is assumed that in hornless animals a gene for horns has either been lost or is inhibited. It is equally probable that no gene has been lost and that nothing is inhibited. Secondly, it is assumed that one inhibitor is inferior to one horn-gene in power, but that two inhibitors surpass one horn-gene, yet two inhibitors are themselves overpowered by two horn-genes; without all three of these ungrounded assumptions of the relative valency of imaginary genes the explanation fails altogether. Further, it is assumed that the female is capable of carrying two inhibitors, but the male only one. And, finally, when this colossal structure of hypothesis encounters one well-known physiological fact, the result of castration, that fact is calmly brushed aside. Is this a desirable extension of Mendelian interpretation?" (See Castle, W. E., "Are Horns in Sheep a Sex-Limited Character?" Science, n. s., vol. 35, Apr. 12, 1912, p. 575.)

These terms can also be defined from the standpoint of correlation, though including a wider range of phenomena than are usually considered in statistical studies. Characters may be called symphanic when they show mutual or positive correlations of expression, antiphanic when they show negative or antagonistic correlations, and paraphanic when there is an absence of correlation.

It may be objected that more words are unnecessary, since the facts can be stated in terms of correlation. As long as the facts are viewed only from a mathematical standpoint the terminology of correlation may be sufficient, though it is often inadequate if not actually misleading, for biological statement of the facts. Negative correlation (antiphany) and absence of correlation (paraphany) are no less positive facts from the biological standpoint than the cases that are described as positive correlation (symphany). It may be that the meaning of the term "correlation" will become modified in practice so as to have more of a biological and less of a mathematical significance. The object to be gained in the meantime is the recognition of the practical importance of the study of expression relations from the biological standpoint, instead of depending upon the mathematical method of the empirical discovery of such relations.

Some writers have concluded that correlations are too rare to be of use in practical breeding, because of the many cases of apparent absence of correlation that result when measurements are applied at random, in attempting to make empirical discoveries of correlations. While it is probably true that the paraphanic characters outnumber the symphanic and antiphanic characters, it has also to be considered that many of the so-called characters employed in the search for correlations represent merely formal statements, framed without regard to the real relations of expression.

With characters framed from the biological standpoint it is to be expected that the laws of correlation, of variation, and of coherence of characters in hybrids will be found to have very general application, as long since recognized by one of the greatest of botanical naturalists.

> In all stable groups, whether of higher or lower rank, there should be some correlation of structure in every organ, which it is the systematist's part to trace out and rate at its true value.[1]

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[1] Spruce, R. Equatorial-American Palms. Journal, Linnean Society, Botany, vol. 11, 1871, p. 91.

MEASUREMENT OF EXPRESSION RELATIONS.

It is often interesting, and may sometimes be important, to make accurate determinations of the extent of correlation in the expression of two characters in a particular group of plants or animals. Elaborate systems for measuring and expressing different degrees of correlation have been recommended by mathematical biologists. If these relations of expression represented natural constants like the atomic weights of elementary substances or the angles of crystals, the labor of very accurate determination of all such relations might be justified. But there is no reason to believe that relations of expression are less varied than other biological phenomena. They are often changed in the same group or even in the same individual under different conditions of existence. Correlations will appear constant, of course, as long as the expression of the characters is not changed, but any influence able to disturb expression is likely to interfere with correlation as well.

It is manifestly desirable that biological study of expression relations precede mathematical study to avoid the waste of labor in ultra-accurate determinations of relations that have little or no biological significance. An almost infinite number of mathematical relations can be formulated among the parts of any of the higher plants or animals. If the measurements of all conceivable relations were considered necessary as a basis of biological study the future of biological science might well be considered hopeless. It is a mistake to consider the making of statistical measurements as an independent method of biological investigation. The importance of biological statistics resides almost entirely in their value as a more direct and accurate method of stating relations revealed or suggested by familiarity with facts gained through other methods of investigation.

When mathematical analysis precedes biological analysis the facts are likely to be brought into entirely artificial and misleading relations. A fact that appears altogether trivial from the statistical standpoint may be extremely significant from the biological standpoint, such as the appearance of a few individual mutations among thousands of unvaried examples of a pure stock. The most striking example of correlation, where groups of characters derived from the same parent show coherence in expression, are capable of direct observation, without the need of mathematical demonstration. Mathematical statements of such compound relations are difficult to frame, and the facts are not rendered any more intelligible or more practically useful after such treatment. In critical cases it might be important to learn which of a series of coherent characters were more closely associated, but this would require only a comparison of simple correlations. There would still be no practical need of reducing a compound correlation to a mathematical expression.

The idea that all biological facts are enhanced in value or interest by being stated in mathematical form is to be understood as one of the results of the undue emphasis generally placed on mathematical studies in educational institutions. It is easier to occupy the student with mathematical formulæ than to develop his interest in the multitudinous details of plant or animal life, and allow him to secure the familiarity with nature that is necessary as a basis of biological judgment. The tendency of educational institutions is to formal instruction in biology, as in other subjects. The mathematical substitutes for biology afford more satisfactory materials for pedagogic purposes, and especially for dealing with large bodies of students.

Coefficients of correlation between different characters, such as stature and susceptibility to disease, are useful, of course, for insurance companies interested in the longevity of mixed populations, but nobody has explained how such coefficients are to be used by the breeder of select strains. Selection, with the breeder, is not a matter of taking average risks on a large number of individuals, but of finding and propagating the best individuals. Such selection must be based on biological types, not on mathematical types or statistical averages.[1]

To say that a variety or type of cotton has a tendency to variation in a certain direction may seem too loose and indefinite for scientific purposes. Writers who aim at mathematical precision often object to such statements. But when the facts themselves are indefinitely variable it is not unscientific to describe them in appropriate language. To say that a stock has a tendency to vary merely means that some individuals are likely to show the variation in question, while others do not, which is true of many characters. While it is interesting in all such cases to make more accurate determinations of the extent of variations in different stocks or in different conditions, it is first necessary to recognize that the tendency exists. To record such as observation is quite as proper and as truly scientific as for an explorer to record the general position of a range of mountains, though he may not be able to climb the peaks or even to establish their exact locations.

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[1] Bateson has called attention to the fact that mathematical treatments may conceal biological differences which are apparent from direct observation: "As a matter of fact, even in the case of Nigella, differentiation was detected not by the seriations, but by common observation. When the differentiation has been once detected, its influence can be seen in the seriations. This is a mere accident. If the material had happened to contain a certain proportion of a second race with a 'mode' on 10 or 13 and a secondary 'mode' on 8—a condition familiar in plants (from F. Ludwig's beautiful researches)—the differentiation might have been completely masked in the seriations. As it is, the seriations alone contain nothing which prove the existence of differentiation. We happen to know otherwise that high numbers are associated with centrals and lower numbers with laterals. This is not revealed by the seriations. For all they show, the irregular distribution might be due to ordinary discontinuous variation, obeying the laws which F. Ludwig has shown such distributions commonly obey." (See Bateson, W., "Heredity Differentiation and Other Conceptions of Biology." Proceedings, Royal Society of London, vol. 69, p. 205.)

It is not surprising that investigators who approach biology from the standpoint of the physical sciences, without becoming familiar with the protean diversity of species in nature, should overlook the essential flexibility of the processes of reproduction. Elaborate measurements often convey misleading impressions of regularity or secure too exclusive attention to phenomena that lend themselves to mathematical forms of expression. The following statement in a recent review of biometrical literature affords further evidence that this danger is beginning to be appreciated:

> One who follows the current literature of agricultural science, in a broad sense of the term, can not fail to be struck with the rapidly increasing use of these mathematico-statistical methods during the last few years. In so far as the methods are correctly and appropriately used this is a most commendable movement. But it must always be kept in mind not to let admiration for the method per se blind one as to the real significance and importance of the biological problem attacked. The futility of dealing biometrically with data or problems which lack a sound biological basis is obvious. The indiscriminate application of biometric methods to all kinds of data is easily seen upon critical examination to have only so much value or validity as resides in the original data themselves. It is particularly important that this point be kept in mind in agricultural work along biometric lines, because of the great ease with which mere statistics can be collected in this field and the consequent temptation to collect them without critical consideration of their meaning and worth.[1]

UNIFORM EXPRESSION OF CHARACTERS.

Uniform expression of characters is secured in domesticated varieties by vegetative propagation or by selective line breeding. It is not a typical condition of heredity in normal species nor an ideal in eugenics. Agricultural breeding is largely a problem of replacing diverse stocks with more uniform breeds or strains. The object of general investigations of breeding is to learn the best methods of producing uniform strains of domestic plants and animals and of preserving uniformity through many generations.[2]

The tendency to look upon uniform expression of characters as the normal condition of heredity is reflected in the terms that have been proposed for the designation of uniform groups of plants or animals, such as "pure race," "pure line," "elementary species," "biotype," and "genotype." Though proposed in connection with different theories, these words all have reference to the idea of heredity as naturally fixed and definite, as shown in uniform groups or series of individuals. The existence of normal species of diverse interbreeding individuals is disregarded.[3]

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[1] Pearl, Raymond. Some Recent Studies on Variation and Correlation in Agricultural Plants. American Naturalist, vol. 45, no. 535, 1911, p. 415.

[2] Cook, O. F. The Superiority of Line Breeding over Narrow Breeding. Bulletin 146, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1909.

[3] The word "genotype," which several writers on heredity have adopted recently from Johannsen, is objectionable from the standpoint of systematic biology because it was already in use to designate the specimen or species that serves as the type of a

In cotton, and doubtless in other open-fertilized crops, a breeder sufficiently familiar with the peculiarities of his type can maintain a higher degree of uniformity by roguing out the aberrant plants than by the use of progeny methods, with roguing neglected. The uniformity of the Triumph cotton, as maintained by the originator of the variety, Mr. Alexander Mebane, at Lockhart, Tex., was found, some years ago, to be greater than that of any of the varieties that had been developed by the use of the progeny rows. Strictly speaking, the pure-line or pedigree method of breeding is not applicable to cotton in actual practice. The methods of selection that have been worked out for wheat and other self-fertilized types can not be expected to produce the same results with open-fertilized plants like cotton. If the parent plants are not selected with care as representatives of a single varietal type, the crossing that takes place in the progeny rows is the same as when different varieties are planted together for comparison and testing. Nobody would seriously propose to save the seed of such plantings with the idea of securing pure stocks. Without strict adherence to the varietal type, the progeny-row method is not only unable to produce uniform varieties of cotton, but is more likely to maintain diversity of continued crossing. If a plant has been selected because of any divergence from the varietal type, the seed ought not to be grown in the same block with the progenies of plants that represent adherence to the type. In other words, variations and progenies should be recognized as different kinds of material and kept apart. The breeding of new varieties by the selection of superior variations is a task quite different from that of preserving the uniformity of superior strains by selecting for close adherence to type. Varieties are originated by preserving variations, but are preserved by rejecting variations.

A thoroughly uniform variety represents a complete suppression of the normal diversity or heterism usually to be found among the members of natural species. Though differences due to external conditions should not be allowed to interfere with the recognition of uniform groups, there is a practical necessity of placing the members of a group as nearly as possible under the same conditions if uniformity of expression is to be judged. The basis of selection to maintain uniformity is not a mere ideal type or artificial standard estab-

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genus, as proposed by Schuchert in 1897. (Science, n. s., vol. 5, p. 639; see also Bather, F. A., Science, n. s., vol. 32, Dec. 30, 1910, p. 953.) The following new definitions have been offered recently by Dr. G. H. Shull: "Genotype, the fundamental hereditary constitution or combination of genes of an organism." "Biotype, a group of individuals possessing the same genotype." "Pure line, a group of individuals traceable through solely self-fertilized lines to a single homozygous ancestor." In an earlier paragraph is the following explanatory statement regarding pure lines: "There is another prevalent misconception regarding 'pure lines' to which attention needs to be called. The word 'pure' in this connection does not refer to the genotypic equality of the individuals, but only to the exclusion of all crossing as a source of genotypic differentiation." (See Science, n. s., vol. 35, Jan. 5, 1912, p. 28.)

lished by score-card reckonings of the values of different characters, but is an actual, visible type, represented by the normal members of the variety as they exist in the same field. Familiarity with the variety is therefore to be considered as the first qualification for undertaking the work of selection or roguing to maintain the uniformity of a select strain.[1]

As the expression of the characters varies with conditions, each field of cotton may need to be judged by a standard of its own. Even in parts of the same field, plants that belong to the same uniform stock may show considerable differences that prevent the application of any absolute standard, except the standard of uniformity itself. Every plant is to be rejected that shows any sign of being different from its neighbors. Superior variations need to be removed, no less than inferior variations.

This method of preserving uniform varieties by rejecting all deviations from the type has often been confused with mass selection but is essentially different. Mass selection simply preserves individuals or lines of descent that show one or more desired characters in a special degree, without requiring that such superior individuals shall conform in other respects to a definite varietal type. The object of conservative or agronomic selection is not to originate or to improve varieties but to maintain the uniformity of superior strains already separated. It is worth while to compare this form of selection with others and to consider their relations to uniformity of expression. The different forms of selection may be described briefly as follows:

Natural selection represents an irregular and usually a partial application of many standards. Adverse conditions are not applied equally or at the same time to all the members of a natural species. The result of natural selection is to discriminate against individuals and lines of descent that are inferior with respect to the various requirements of existence under natural conditions, but such selection would not be expected to develop a state of uniform expression of characters.

Mass selection involves a more consistent application of one or more standards of superiority, but without reference to uniformity in other respects. The result of mass selection is to secure a higher average of expression of desired characters, but without establishing any general uniformity by the separation of the families or lines of descent that have the most regular expression of characters.

Individual selection goes beyond mass selection by choosing superior individual plants to serve as parents of select strains. It avoids crossing among the descendants of different types of superior individuals, which is one factor of diversity in groups maintained on the basis of mass selection.

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[1] Cook, O. F. Cotton Selection on the Farm by the Characters of the Stalks, Leaves, and Bolls. Circular 66, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1910.

Progeny or centgener selection is a more careful form of individual selection based on comparison between progenies of superior individuals to determine the regularity of expression of characters, the so-called transmitting power of the parents of the different progenies.

Agronomic selection is the rejection of all offspring or descendants that deviate from the standards of the superior parent or progeny group.

As a means of preserving the uniformity of select strains agronomic selection supplements progeny selection and is more effective. Instead of relying entirely upon the progeny or pedigree, the uniformity of the stock is guarded in each generation by inspection of all individuals that are to be used for purposes of propagation, in order to reject any individuals that are inferior or that have varied from the type.

With many domestic animals, and with some plants, it is practicable to renew individual or progeny selection with each generation. But with cotton and similar open-fertilized annual field crops it is much more difficult if not quite impracticable to apply these methods on a sufficient scale to secure select seed in commercial quantities. Hence the necessity in such cases of recognizing agronomic selection or roguing to type as a regular responsibility of every seed grower or farmer who desires to maintain a uniform variety of cotton. And hence, also, the desirability of distinguishing this method of selection, based on the recognition of a definite type, from ordinary mass selection by score cards or other partial standards, without primary reference to uniformity of expression.

The necessity of agronomic selection as a means of preserving the uniformity of superior varieties is not appreciated from the standpoint of theories that look upon uniformity of expression as a natural condition disturbed only by hybridization or mutation. Apart from such accidents, it is assumed that a pure line, once separated, will remain uniform indefinitely. This theoretical assumption is often allowed to obscure the practical necessity of continued selection.

Johannsen's theory of genotypes and biotypes contemplates a condition of absolute fixity of expression, even to the extent that there shall be no heritable differences among the later descendants of the stock. Fluctuations due to differences of environment are admitted, but nothing is supposed to be gained or lost by further selection. If any definite variation can be detected the stock is pronounced impure or a mutation is supposed to have occurred. In view of the fact that no such absolute and permanent uniformity of expression of characters is secured, even by vegetative propagation, it may be doubted whether this idea of genotypes and biotypes represents anything that has an objective existence. Judged by the standards of the genotype hypothesis all stocks must be considered impure or else subject to very frequent mutation.[1]

By selection of the lines of descent that show the most regular expression of a desired set of characters, relatively uniform groups are obtained, but these are not biotypes or genotypes in the sense of primary or antecedent states of heredity. They are merely incidental or artificial exceptions to the general law of diversity. Their uniformity is no indication of pure ancestry, but merely a result of the restriction of descent to narrow lines or to a single parent, in species capable of self-fertilization or vegetative propagation. Uniform groups secured by special methods of reproduction are not more natural or more typical of the general conditions of heredity in plants and animals than identical twins would be as examples of heredity in the human species. Twins are not more pure of ancestry than normally diverse children born of the same parents, nor do they afford any reason for believing that a race of uniform ancestors ever existed.

There can be no objection, of course, to the study of identical twins or of other uniform groups of animals and plants by any refinement of mathematical methods of investigation, but mathematical elaboration should not be allowed to mislead us regarding the biological nature of such groups. Their suitability for mathematical treatment does not make them types of normal heredity. Instead of being biotypes or genotypes, select strains do not represent the natural state of heredity in which life and generative power are maintained, but an artificial condition of uniformity that leads finally to weakness and extinction.

The theory of genotypes has met with prompt acceptance from mathematical writers on heredity, but this should not be allowed to obscure the biological facts that make agronomic selection necessary. It is natural that mathematicians should prefer to deal with something that appears definite and fixed, something adapted to their methods of elaboration. But there is nothing as yet to indicate that the field of normal heredity presents any such constants as mathematicians desire to discover. The unknown quantities are too numerous and too intricately related to be resolved by any refinement of mathematical analysis. Biological analysis is a necessary preliminary, not only to distinguish the different factors, but to learn something of their relative importance and interrelations.

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[1] The statistical evidence offered by Prof. Johannsen as the basis of the genotype theory was reviewed by Yule and pronounced inadequate. (See Yule, G. U., "Professor Johannsen's Experiments in Heredity," New Phytologist, vol. 2, 1903, p. 235.)

As affording more adequate means of describing the results of biological analysis, mathematical precision of quantitative determinations is very important. But mathematical elaboration considered as a method of investigation is as futile as the logical or metaphysical elaboration formerly so popular and now so little regarded. Zeal for measurement is not the same as biological interest and familiarity with the characters or behavior of the plants. Mathematical biologists have, of course, no conscious intention of placing figures before facts, but the method is often allowed to influence the choice of materials used as the basis of inference. Uniform groups represent a mathematical ideal, and this leads to their acceptance as the normal condition of heredity, even in cases where they are known to be an artificial product of the breeder's art.[1]

PHYSIOLOGICAL STANDARDS OF EXPRESSION.

The extent to which a stock will appear uniform from a statistical standpoint must depend largely upon the characters that are chosen and the perfection of the system of measurements. Varieties that have been brought to a high degree of uniformity in some characters may continue to show a wide range of differences in other respects. It is known, for example, that the types of Indian corn selected for uniformity of ear characters often show notable diversity in vegetative characters. The same is true of the sugar beets that have been so persistently selected for high sugar content but with little or no regard to the establishment of uniform types of plants.

And even though the members of a stock express the same set of characters in the morphological sense, different degrees of physiological strength or weakness may be manifested in the more or less vigorous growth of the vegetative parts or in the size or number of seeds. Such differences in vigor or productive efficiency are as likely to be inherited as morphological peculiarities, especially in line-bred stocks. There is no reason to expect that any two lines of descent would represent absolutely the same level of physiological efficiency, though it is to be expected that many lines of a carefully selected stock would agree within the limits of experimental error in testing. In view of the fact that differences between experimental rows of the same stock grown under the same conditions are seldom brought within 5 per cent and often run to 15 or 20 per cent, it is easy to understand that considerable differences may often remain hidden within the range of experimental error. Failure to detect such differences experimentally affords small reason for declaring that they do not exist. Some writers have considered vigor and fertility as

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[1] Cook, O. F. Pure Lines as Artifacts of Breeding. American Naturalist, vol. 43, 1909, p. 241.

"unit characters," but even on that assumption the possibility of slight differences would need to be admitted.

The mistake of relying upon pedigrees or upon morphological uniformity of expression of characters as standards of practical breeding is now widely recognized. Selection of superior individuals as parents of pure strains is now based on the physiological standard of actual performance of the progeny, instead of upon ancestry alone. Yet even this refinement affords no complete assurance of maximum yield, for it has been found that the precautions applied to insure the purity of the stock have the effect of reducing the physiological efficiency of reproduction. Instead of remaining equal to the superior ancestor or to each other, pure lines of descent show different degrees of vigor and fertility. Even plants that are propagated from cuttings do not remain forever the same. Breeders familiar with plants like strawberries and potatoes recognize the fact that varieties eventually run out; that is, decline in fertility, vigor, or resistance to disease. A recent writer reports a reduction of the size of the meshes of the network of veins in the leaves in old grapevines and considers this as a phenomenon of senility.[1]

Persistent selection excludes degenerate individuals and lines of descent. The stock is kept nearer to the standard of its best members, but the utmost refinement of pure-line breeding may still fall short of the full possibilities of production. In the very nature of the case a select strain separated from the normal network of descent of the species and artificially excluded from crossing is placed at a disadvantage in relation to vigor and fertility. The physiological value of crossing between different lines, as occurs in the network of descent of natural species, must be taken into account if the vigor and fertility of domesticated plants and animals is to be maintained. This physiological factor of heredity has recently received recognition in connection with the corn crop, as the following statements will show:

> Increased yields are obtained by making the yield of the individual plants more uniform, even when the full possibilities of production are not approached. The best plants of a highly bred variety are not conspicuously more prolific than the best individuals in fields from unselected seed * * *.
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> Though necessarily impeded by inbreeding, important advances in yield have been made by means of close selection, but the value of these improvements

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[1] "Since the leaves borne by cuttings showed but slight increase in the proportion of carbohydrate-producing tissue as compared with those on the original plant, it would appear that vegetative propagation can not and does not produce a young plant. The fact that the normal span of life for woody trees and vines extends in some cases over hundreds of years accounts for the fact that the approach of senility in vegetatively propagated plants is not more obvious. Plants which naturally reproduce by seed will tend to 'run out' after long-continued vegetative propagation, ultimately dying of senility, and it is therefore incumbent upon our plant breeders to develop new varieties from seed to take their place." (See Benedict, H. M., "Senility in Meristematic Tissue." Science, n. s., vol. 35, Mar. 15, 1912, p. 422.)

> should not be allowed to obscure the fact that the full possibilities of production are not reached until the increment of vigor obtained by crossing has been added.[1]

> Continued selection * * * yielded very promising results with corn during the early years of its application, but the later generations failed to fulfill this promise. Definite reasons for this comparative failure in the corn-breeding work of the United States can now be given, for within the last few years investigators have arrived at some understanding of the underlying principles concerned. These principles are yet but imperfectly understood, but they are sufficiently clear to show that practical corn breeding must undergo a radical change in method if it is to take advantage of the full possibilities which lie open to it * * *. All methods now in use for the improvement of corn are by the application of the selection principle and tend sooner or later toward inbreeding. As corn naturally produces the best results when crossed, we hold that all methods now used are wrong unless combined with some method for continuous crossing.[2]

The neglect of this factor of vigor obtained by crossing is only one of many examples of a general tendency of scientific men to disregard the practical value of any principle or factor that they are unable to explain. Why it is that crossing gives increased vigor is still quite unknown, but the fact has been recognized since the earliest times and has been repeatedly verified by scientific experimenters. Half a century ago Darwin performed many experiments and reviewed a large volume of evidence on the effects of crossing and reached general conclusions which no subsequent writers have overthrown, though such facts have often been disregarded in the discussion of abstract theories. The following statements show the results of Darwin's study:

> On the other hand, long-continued close interbreeding between the nearest relations diminishes the constitutional vigor, size, and fertility of the offspring, and occasionally leads to malformations, but not necessarily to general deterioration of form or structure * * *.

> These two great classes of facts, namely, the good derived from crossing, and the evil from close interbreeding, with the consideration of the innumerable adaptations throughout nature for compelling, or favoring, or at least permitting the occasional union of distinct individuals, taken together, lead to the conclusion that it is a law of nature that organic beings shall not fertilize themselves for perpetuity.[3]

These opinions were formed in spite of the fact that Darwin was familiar with a few plants that seemed to be specially adapted for self-fertilization. But with his wide knowledge of the organic world, he was inclined to look upon such cases as exceptions and preferred to establish his conclusions on the more general condition.

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[1] Collins, G. N. The Importance of Broad Breeding in Corn. Bulletin No. 141, pt. 4, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 42.

[2] Hayes, H. K., and East, E. M. Improvement in Corn. Bulletin 168, Connecticut Agricultural Experiment Station, 1911, pp. 3 and 9.

[3] Darwin, Charles. "The Variation of Animals and Plants Under Domestication," vol. 2, p. 159.

Since Darwin's time the biological evidence for the universality of crossing in natural species has continued to increase. The wild types or less "improved" varieties of cereals and other domesticated species have been found to be cross-fertilized. It has also been perceived that even highly specialized adaptations to aid in self-fertilization afford no reason for concluding that the same species does not profit by occasional crossing.

Some species are better adapted than others for maintaining their existence by vegetative propagation or self-fertilization, but it does not appear that any of the higher types of life, either plant or animal, are able to exist permanently without crossing.

The cotton plant is one of many that are adapted for crossing as well as for self-fertilization. In the Egyptian type the stigmas are exserted beyond the stamens and fertilization is more dependent on crossing than in Upland varieties. Here the stigmas are partly immersed among the stamens, so that the opening of the anthers brings the pollen into direct contact with the stigmatic surfaces. That varieties will be found to differ in their ability to tolerate long periods of self-pollination or strict selection is to be expected. Experiments with the artificial self-pollination of Upland and Egyptian cotton do not seem to have furnished any evidence of injury to the later generations of the plants. There is a frequent failure to set seed from artificial self-pollination, but this is also true of artificial cross-pollination. Adverse effects from self-fertilization have been reported recently in Indian cottons.[1]

How the effect of crossing is produced is still as much of a mystery as the other processes of heredity, but the lack of an explanation need not prevent a recognition of the fact, nor of its great physiological importance. The old idea was that inbreeding resulted in some positive injury or poison to the offspring, but from the present point of view we can consider the evil effects as due to an absence of some positive quality necessary for the activity of the protoplasm, some stimulating tension or antagonism that may be aroused by the presence of two kinds of protoplasm derived from different lines of descent. Lack of the stimulation or bracing effect of crossing allows the mechanism of heredity to run down; vigor and fertility decline, and degenerative variations appear.

EXPRESSION REGULATED BY SELECTION.

The benefits of selection must appear greatest in a stock that is declining in productive efficiency. The larger the proportion of small or weak individuals or progenies the greater the contrast with the superior lines that are separated by selection. The rejection of the weaker or more inefficient lines brings the average of the stock back toward the standard of its best members, but it is a practical error to expect that such a standardization of expression will be maintained without further selection. The functions of selection in regulating or stabilizing expression and in preserving the uniformity and productive efficiency of superior stocks is quite as important as that of separating the superior lines to form new varieties.

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[1] Leake, H. M., and Prasad, R. Notes on the Incidence and Effect of Sterility and of Cross-Fertilization on the Indian Cottons. Memoirs of the Department of Agriculture in India, Botanical Series, vol. 4, January, 1912, p. 37.

The separation of a select strain of a plant like cotton is an important agricultural improvement, for it enables a larger crop and a better quality of fiber to be produced. But this does not mean that the strain itself is being improved or placed in a better physiological condition by being kept from crossing with other varieties. There is no reason to suppose that a variety or strain of cotton would last indefinitely, even if it were selected with the utmost skill and persistence. But for practical reasons it is important to know how to preserve select strains in uniform condition as long as possible, so that they can be utilized to the fullest extent for purposes of production. The farmer has the same reason for removing the degenerate plants from his seed field as he has for pulling out the weeds, and a further reason in the fact that the progenies of the good plants will be rendered inferior by crossing if the bad plants are allowed to remain.

A well-bred type of cotton might appear to support the idea that permanent uniformity of expression had been established, if observation were confined to a limited number of plants grown under favorable conditions. But if sufficiently large numbers are examined, or numerous experimental plantings are made in different localities, many definite variations or mutations are likely to be found. From a statistical standpoint such variations may appear insignificant, but they throw light on the degeneration of varieties. In one examination of the Triumph variety of Upland cotton growing under its native conditions at Lockhart, Tex., only three definite variations were detected in about 50 acres. On the other hand, about 2 acres of cotton raised from seed of the Lockhart stock at Kerrville, Tex., showed frequent mutative variations.[1]

If the uniformity of the Triumph cotton at Lockhart had not been ascertained it would have been easy to make the usual assumption that the stock had not been carefully selected, but this theory was definitely excluded by the uniform behavior of the Triumph stock, not only at Lockhart, but in many other places in Texas and other States where very uniform fields of cotton have been grown from Lockhart seed.

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[1] Cook, O. F. Local Adjustment of Cotton Varieties. Bulletin 159, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1909.

Some farmers believe that the Triumph stock is especially liable to a breaking up when carried to new localities, though it does not appear that any adequate comparisons have been made with other varieties to determine this point. That such numerous and definite variations should appear in one of the most uniform and carefully selected varieties of cotton is interesting from the standpoint of heredity. It also suggests an important question in breeding, whether there are not natural limitations in uniformity, as well as limitations in vigor and fertility, in varieties that are carefully selected for the expression of a single set of characters.

Renewed assurances of the value of Mendelism for the establishment of pure lines has been given by Bateson in a recent address. The existence of any general tendency to degeneration in pure-bred strains is denied, the possibility of degeneration by failure of expression of certain characters as in albinos and short-jointed forms like the cluster cottons being left out of account. The assumption that all variations must be due to crossing or to incomplete analysis into pure lines is reasserted. The theory is evidently to be retained, even though experimental facts have to be discredited. That degenerate variations show alternative inheritance like Mendelian hybrids is taken to mean that crossing must have occurred. But if it can be positively shown that the variations are not due to crossing, the rogue throwers must constitute a distinct class which can be removed by Mendelian analysis and thus leave a permanently pure stock.[1]

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[1] "One of the greatest advances to be claimed for the work is that it should induce raisers of seed crops especially to take more hopeful views of their absolute purification than have hitherto prevailed. It is at present accepted as part of the natural perversity of things that most high-class seed crops must throw "rogues," or that at the best the elimination of these waste plants can only be attained by great labor extended over a vast period of time. Conceivably that view is correct, but no one acquainted with modern genetic science can believe it without most cogent proof. Far more probably we should regard these rogues either as the product of a few definite individuals in the crop, or even as chance impurities brought in by accidental mixture. In either case they can presumably be got rid of. I may even go further and express a doubt whether that degeneration which is vaguely supposed to be attendant on all seed crops is a physiological reality. Degeneration may perhaps affect plants like the potato, which are continually multiplied asexually, though the fact has never been proved satisfactorily. Moreover, it is not in question that races of plants taken into unsuitable climates do degenerate rapidly from uncertain causes, but that is quite another matter * * *. If the rogues are first crosses the fact can be immediately proved by sowing their seeds, for segregation will then be evident. For example, a truly round seed is occasionally, though very rarely, found on varieties of pea which have wrinkled seeds. I have three times seen such seeds on my own plants. A few more were kindly given me by Mr. Arthur Sutton, and I have also received a few from M. Philippe de Vilmorin—to both of whom I am indebted for most helpful assistance and advice. Of these abnormal or unexpected seeds some died while germinating, but all which did germinate in due course produced the normal mixture of round and wrinkled, proving that a cross had occurred. * * * I anticipate that we shall prove the rogue throwers to be a class apart. The pure types then separately saved should, according to expectation, remain rogue-free, unless further sporting or fresh contamination occurs." (See Bateson, W. "Genetics." Popular Science Monthly, vol. 79, no. 4, October, 1911, pp. 319–321.)

No breeder would deny, of course, that varieties or lines of descent differ in the production of degenerate individuals as well as in other ways. This is a feature that is often taken into account in the choice of varieties of garden crops. But this is apart from the main issue whether there are any pure lines of descent that remain uniform in all their members and never throw any rogues. To admit that further sporting is likely to occur is to abandon the claim of permanent uniformity. If the Mendelian doctrine is of practical value, it should be possible to find a permanently uniform pure-bred line of descent in some species of plant or animal, one that could be multiplied to large numbers and subjected to different conditions of existence without sporting.

What the cotton industry needs even more than the breeding of new varieties is the development of a system for preserving varieties from deterioration by removing the rogues as soon as they appear. Whether the object of uniformity is to be attained through the medium of organized efforts of cotton-growing communities, public seed-control stations, or through the activities of private breeders and seed growers, the present need is to educate the public in the importance of uniformity and the need of continued selection as a means of preserving superior varieties. To rely on the Mendelian assurance of securing permanent uniformity by pure line breeding would mean a further postponement of consideration of practical measures that are so obviously needed.

EXPRESSION RELATIONS OF COLOR CHARACTERS.

Though color characters and others that depend directly on chemical reactions most commonly show the Mendelian form of alternative expression, two quite different relations are presented by the color characters of cotton. In hybrids between the Egyptian and the Upland types of cotton the lemon-yellow color of the Egyptian petals usually appears in plants that show a preponderance of other Egyptian characters, but very rarely in plants with distinctive Upland characters. A few hybrid plants, perhaps half a dozen out of as many thousands, have been found with the incongruous combination of Egyptian color with Upland form, but these individuals were infertile and abnormal in other respects. The combination of white petals with Egyptian characters is less incongruous and much more frequent, in some Egyptian fields about one plant in a hundred. Some of the white-flowered Egyptian plants are sterile or otherwise malformed, but many are fertile and apparently normal.

The purple spot at the base of the petals of the Egyptian cotton is inherited in quite a different manner. It is often definitely expressed in hybrid plants with white petals and a preponderance of the other Upland characters, while plants with yellow petals and the other Egyptian characters may have a very faint spot, or none at all. Unlike the general colors of the petals, which are symphanic with other characters of the same parent and antiphanic to those of the other parent, the expression of the purple-spot character shows a much more indifferent or paraphanic relation with other characters. Even among the conjugate hybrids there is a wide range of variation in the expression of the purple spot.[1]

Nevertheless, the spot character is not without definite expression relations. In a study of the Jannovitch variety of Egyptian cotton from the standpoint of contamination with the inferior Hindi type, some plants were found that seemed to depart from the Egyptian characters only in having the spot of a paler shade of purple than usual. At first this difference was considered quite insignificant, because of the frequent variability of the spot. Even on the same plant there is often a wide difference, some flowers having a well-developed spot and others none at all. But in the autumn it appeared that all of the Jannovitch plants with the pale-spotted flowers produced only small bolls. The recognition of the fact that some of the plants had only pale spots made it possible to learn that such plants also had limitations in the size of the bolls.

The prospect of discovering such a relation by a general system of measurements of spots and bolls would have been very small in spite of the large amount of labor that would have been required. Now that the fact has been recognized, the working out of a mathematical expression of relation between the paling of the spots and the reduction of the size of the bolls might be an interesting mathematical diversion, but it seems quite unnecessary for biological interest or agricultural application. The use of the correlation lies in the recognition of the pale spot as a symptom of degenerative variation or departure from the characters of the Jannovitch type. It affords another means of guarding the uniformity of such stocks by selection.

EXPRESSION RELATIONS OF STRUCTURAL CHARACTERS.

In the Upland type of cotton an abundance of fuzz on the seed is antiphanic to long lint but symphanic with abundant lint. If the selection of Upland cotton be directed exclusively to the production of longer lint, the fuzz tends to disappear and the lint also becomes more sparse. If abundance of lint is to be maintained, selection for length of lint needs to be restricted to plants with fuzzy seeds. The production of fuzz represents a favorable condition for the production of abundant lint. Abundant lint is sometimes found on naked seeds, but this is opposed to general tendency and represents an unstable condition of expression. Later generations of naked-seeded selections have shown persistent tendencies to sparse lint in spite of repeated selection to maintain abundance.

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[1] Cook, O. F. Hindi Cotton in Egypt. Bulletin 210, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1911, p. 31.

The symphanic relation between fuzz and lint does not hold at the other end of the series of variations, for with an excessive development of fuzz the lint usually becomes less abundant. This has been shown repeatedly during the acclimatization of the Kekchi cotton, and the same tendency has appeared in experiments with seed selection in the Columbia cotton. In a series of such selections compared by Mr. Argyle McLachlan the plants that were raised from seeds with a rather thin short fuzz showed a general superiority in lint characters over those raised from seeds with the heaviest coating of fuzz. A new short-staple variety with a very high percentage of lint, recently announced by a Georgia breeder, has unusually short uniform fuzz. Seeds with too much fuzz doubtless represent a partial or complete absence of the normal specialization of the two kinds of hairs on the seed coat.

Long lint is also symphanic with narrower and more pointed forms of bolls and antiphanic to short rounded bolls. A variation toward a more rounded form of boll is seldom or never accompanied by variation toward longer lint, whereas variations toward narrower and more pointed bolls often show longer lint. This relation holds among different species and varieties as well as among individual diversities of hybrids and selected stock. The coherence of these characters is evidently biological and phyletic, unlike the ordinary correlation that exists between abundance of lint and increased diameters of bolls. The fibers do not lie extended in the bolls, but are packed about the individual seeds. It is easy to understand why more abundant lint should involve thicker bolls, but there is no mechanical requirement of longer bolls to contain the longer lint.

The practical importance of the relation between the form of the boll and the length of the lint does not depend upon its being stated in mathematical terms. The breeder has an adequate demonstration of its value when he finds himself able to predict the relative lengths of lint of different plants by simple inspection of the forms of the unopened bolls. In the great majority of cases the shorter lint will be found in the broader and more rounded bolls. Plants with pointed or tapering bolls will sometimes be found to have short lint, but it is much more rare to find longer lint in more rounded bolls.

A statistical statement of the relation would be likely to give no adequate idea of its practical importance, owing to the great variability of the factors involved. The lengths of the lint fibers differ not only on the same plant but on the same seed. Satisfactory measurements of bolls are also very difficult because of the complications introduced by differences of angularity and taper. The shapes and sizes of bolls differ in the same variety in different places. Even in the same plant the checking of growth by drought may induce smaller and more rounded bolls and shorter fiber. But, in spite of these irregularities, familiarity with the plants usually makes it possible to distinguish at a glance those that show definite deviations from the type of the variety in the direction of more rounded bolls and shorter lint. If elaborate measurements were required to distinguish the variations, the relations of expression would have no practical value in the work of selection.

Another general relation of coherence in the expression of characters in cotton exists between the length of the lint and the number of carpels or locks in the bolls. The Sea Island, Egyptian, and other long-linted types of cotton have fewer locks than the short-staple Upland varieties. The long-staple cottons have three or four locks, but in short-staple cottons a considerable percentage of 5-locked bolls is a regular feature. The same relation is found in hybrids between long-staple and short-staple cotton. Egyptian-Upland hybrid plants that have any 5-locked bolls seldom have long lint, a fact first remarked by Mr. Rowland M. Meade. Likewise among variations of Upland cotton, plants with longer lint generally show smaller proportions of 5-locked bolls.

An analogous relation in the expression of characters not directly connected or commensurable with each other has been reported by Worsley in Capsicum pepper. It was found possible to judge the taste of the fruits from their size and shape. Worsley says:

> I do not claim to have tasted every variety of alleged species of Capsicum, but I have tasted a great number, and I have invariably found that the "hot" tasting properties associated with cayenne pepper are confined to those Capsicum fruits which have pointed apices, the degree of heat varying inversely with the size of the fruit, the smaller being the hotter. Conversely, those fruits with blunt apices are known as "mild" Capsicums, and among these mild fruits the degree of mildness varies with the size, the largest being the mildest.[1]

TWO CLASSES OF HYBRIDS.

The literature of heredity abounds in general statements regarding hybrids. Some writers hold that hybrids are more variable than the parent stocks and others that they are more uniform; some that hybrids are more vigorous, others that they are weaker. But all such generalizations are misleading for the reason that there are two distinct classes of hybrids, governed by different physiological principles inherent in the very nature of the reproductive processes.

Instead of revealing the existence of character units or determinant particles, the study of the formation of germ cells has thrown light on another side of heredity by making it possible to understand the sharp contrasts so frequently found between the first generation of hybrids and the later generations. The cytological discoveries of recent decades have given an entirely new view of the process of conjugation.

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[1] Worsley, A. Variation as Limited by the Association of Characters. Journal, Royal Horticultural Society, vol. 36, pt. 3, May, 1911, p. 599.

Instead of being concerned merely with the union of the germ cells, conjugation has to do with the entire life history of the new organism. Its function is not merely to cause growth to begin but to conduct the whole course of development. The process of conjugation that begins with the union of the germ cells does not come to an end until the new generation has reached the stage of forming its sex cells. It is only the reproductive tissues that can be said to pass through conjugation and go back to the state of simple cells. All the cells that compose the bodies of the higher plants and animals represent specializations of double, conjugating cells, formed by the subdivision of the original double cell or zygote.

In other words, the so-called first generation of a hybrid develops while the conjugation begun by the union of the germ cells is still in progress. What is called the second generation is really the first that represents the results of a complete conjugation. In recognition of these differences the first generation, developed before the original conjugation is completed, has been described as the conjugate generation, while the generation formed by germ cells that have passed through conjugation has been called perjugate.[1]

The results obtained with hybrids in the first generation afford no indication of what is to be expected in the later generations. Nothing could appear more deceptive than the behavior of the first generation of hybrids, until it is recognized that the later generations represent an entirely distinct biological phenomenon. Failure to recognize the fundamental differences between the generations of hybrids is responsible for many vain efforts in breeding.

Conjugate hybrids of cotton are not only much more vigorous than the parental stocks but usually more uniform and more productive, thus arousing lively hopes of developing superior hybrid varieties. But in the perjugate generations none of these promises are fulfilled. The uniformity of the conjugate generation gives place to a multifarious diversity. Many plants are weak and sterile, and many others produce only short and inferior lint. For reasons to be explained in later chapters there seems to be little prospect of breeding hybrid varieties to be propagated by seed. To enable the superior conjugate hybrids to be used for purposes of production will require the development of special methods of producing the seed or methods of vegetative propagation.

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[1] Cook, O. F. Mendelism and Other Methods of Descent. Proceedings, Washington Academy of Sciences, vol. 9, July, 1907, p. 195.

INTENSIFIED EXPRESSION OF CHARACTERS IN CONJUGATE HYBRIDS.

In addition to different combinations and intermediate degrees of the parental characters, hybrids often show a much wider range of expression, beyond either of the parent varieties. In such cases the characters may be described as extraparental, or outside the parents, instead of interparental, or between the parents. Two forms of extraparental expression may be recognized. A character shown in a higher degree than in either parent stock may be described as intensified. A character that disappears or is expressed in a less degree than in either of the parents is said to be suppressed.

One of the most frequent examples of intensified expression in cotton is the appearance of a bright-green color in the fuzz of hybrid seeds even when the parents show only a slight trace of colored fuzz or none at all.[1]

Other examples of extraparental expression are afforded by the nectaries of the involucre of the cotton plant. The full number of nectaries is three, though their occurrence is usually very irregular in both the Upland and the Egyptian types of cotton. But among the hybrids some plants are found with a full complement of three nectaries on all of the involucres, while other plants have very few nectaries or none at all.

The lint characters of hybrids also show intensification beyond the parental standards. In hybrids between Egyptian and Upland cotton there is not merely a dominance of the long-lint characters of the Egyptian parent, but the hybrid lint is usually distinctly superior in length and strength to the lint of Egyptian cotton grown under the same conditions.

The hybrids differ from the parent stocks in having a greatly increased constitutional vigor, as well as in details of expression of the various characters. This increased vigor is manifested both in the larger size of the hybrid plants and in their greater ability to withstand unfavorable conditions that would restrict a full expression of the lint characters in the parental types. It is conceivable, therefore, that the greater length of lint in the hybrids may be due to their increased powers of adaptation to adverse conditions rather than to any more special change of the lint characters.

It has been noticed that the inequality of lint between hybrids and Egyptian plants is greater under very adverse conditions and less under more favorable conditions. This is in agreement with the general fact that the increased vigor and fertility of the hybrid plants is more obvious in places where the growth of the plants is restricted. Where conditions favor a very luxuriant growth of the Egyptian cotton the forms of the Egyptian and hybrid plants become more similar, so that it becomes more difficult to recognize and rogue out the hybrids. Under ideal conditions that would permit a full expression of the lint characters of the Egyptian cotton, the length of the lint of the hybrids might no longer appear to be intensified. But if this view be taken, a very high estimate must be placed upon the increased vigor of the conjugate hybrids as a factor of adaptation, for the lint of conjugate hybrids has been distinctly superior to the lint of the pure Egyptian plants in nearly all of the experiments that have been made.

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[1] Cook, O. F. Reappearance of a Primitive Character in Cotton Hybrids. Circular 18, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1908. See also Suppressed and Intensified Characters in Cotton Hybrids, Bulletin 147, ibid., 1909, p. 8.

The enlarged nectaries, green fuzz, and many other divergent characters that appear in the second and later generations of cotton hybrids must be considered as representing another form of intensification. They do not appear to be results of greater vigor or more effective adaptation but may be in the nature of reversions. A full development of the involucral nectaries is a less specialized condition than a partial suppression of nectaries. Likewise, many of the primitive, unimproved types of cotton have green fuzz similar to that of the hybrids.

The reversion of hybrids to green fuzz may not involve any very serious disturbance of heredity, if it can be accomplished by a mere suppression of the parental characters. If the relations of the parental characters are antagonistic, so that neither of them can come into expression, the course of development is halted at an earlier stage. It may often be difficult to distinguish between suppression and intensification, for an abnormal development of one character may be due to the suppression of some normal inhibitory adjustment, as shown in the tendency of castrated animals to grow to larger size than normal individuals. Thus, a result which in some cases is due to increased vigor may arise in other cases from sterility or some other abnormal condition. The expression of one character represents a condition, favorable or unfavorable, for the expression of another, each character representing a stage in the sequence of development.

That hybridization often has the effect of inducing wholesale reversion or reappearance of ancestral characters has been recognized in such well-known cases as the blue hybrids produced by crossing two white varieties of pigeons, the redder plumage of hybrid fowls, and the reappearance of the incubating instinct in crosses between two nonsitting varieties. Such atavistic reappearances of more primitive characters seem to be almost as frequent as other methods of adjusting the expression relations of contrasted parental characters in hybrids, and as worthy of being taken into regular account in interpreting the phenomena of hybridization.[1]

DEGENERATION IN PERJUGATE HYBRIDS.

The utilization of the increased vigor and fertility of hybrids is a difficult problem because the intensified condition is only temporary. Hybrids between Upland and Egyptian cotton are often very uniform in the first generation, as uniform as the parent stocks, or even more so. But in the second and later generations this uniformity disappears and is not recovered. For three or four generations some individuals continue to show resemblance to the superior first-generation hybrids, but progenies of such plants are diverse, like those that are obtained from the so-called heterozygotes in a typical Mendelian hybrid. The other plants that correspond roughly to the homozygotes of Mendelism return to the expression of the characters of the parental stocks in different degrees and combinations. In many cases there is an almost complete return to the Upland or the Egyptian characters, but such "extracted" individuals very seldom, if ever, attain the parental standards of expression of the lint characters. The Uplandlike plants do not have as good lint as the Upland parent, and the Egyptianlike plants are similarly inferior to the Egyptian parent.

All of the plants that have been selected for the desired combination of Upland vegetative characters and Egyptian lint characters have yielded utterly diverse progenies. In some of the best progenies detailed comparisons were made to see whether any of the desirable individuals were alike, but without finding even two of them with any close similarity in external characters.

In addition to the hybrids that might be supposed to correspond to the Mendelian classes, another group might be recognized to contain the abnormal or aberrant individuals, those that show extraparental expression of characters. Such deviations appear in many organs of the plant, if not in all, including the habits of growth and the system of branching, the form, texture, and hairiness of the leaves, and in all of the recognized characters of the involucres, bolls, seeds, and lint. Many of the aberrant plants produce very little cotton and some are completely sterile. These abnormalities do not appear in the conjugate generation, where extraparental expression is limited to unimportant details, like the greener color of the fuzz. As already stated, the conjugate generation is usually less diverse than the parental stocks, while the perjugate generations are much more diverse than the parental stocks because of the presence of the intermediate and extraparental expression of characters.

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[1] Four general reactions of expression may be recognized in first-generation hybrids. In some hybrids there is a blended or combined (mixophanic) expression of the contrasted characters. In other cases one of the parental characters is suppressed (hypophanic), allowing the opposed character to appear as dominant (epiphanic). When both of the parental characters are suppressed, so that a more primitive character appears, the result may be described as reversive or atavistic expression (palimphanic).

In the hybrids between the Upland and Sea Island types of cotton made originally by Dr. H. J. Webber and bred by progeny-row methods for about 10 generations, somewhat better results have been secured, either because there is more affinity between the Upland and the Sea Island cotton or because the experiments have been carried on for a longer period. In a series of these hybrids planted at San Antonio, Tex., in the season of 1911, the uniformity was sufficient to show some general consistent differences between the progenies, both in habits of growth and in lint characters. There were none of the very abnormal or completely sterile individuals that often appear among the Egyptian hybrids, yet none of the progenies showed any such uniformity as would be demanded in a commercial variety. The lack of uniformity was particularly apparent in the lint characters. Moreover, the lint no longer showed any advantage from crossing with the superior Sea Island cotton. It was distinctly inferior to that of some of the Upland varieties planted in the same place.

The contrast in behavior between the first generation of hybrids and the later generations shows that two different factors or results of hybridization must be recognized. The vigor or increased efficiency of expression in the first generation is followed by a reaction toward weak or inefficient expression in the later generations. These not only fail to maintain the superiority of the first generation, but fall below the standards of the parent varieties.

One way of describing the results is to say that hybridization undoes the work of selection. The uniformity of expression established in parental stocks by selective breeding is lost, and there is a return to an ancestral condition of indiscriminate diversity. But even this may not represent the entire possibilities of change, for many of the aberrant features shown in the second and later generations of hybrids lie far outside the range of the parental characters, and some of them are so abnormal that they can hardly be taken as simple reversions.

One of the most frequent abnormalities is an enlargement of the involucral bracts. This might be considered as a return to an earlier state when these organs were less specialized. Enlargement of the bracts is frequently accompanied by abortion of bolls. The difference between the fertile and the sterile involucres is often apparent on the same plant. Two involucres of a perjugate (second generation) hybrid between Mit Afifi Egyptian cotton and the Willet Red Leaf variety of Upland cotton are shown in Plate II, right-hand figures (*B*). The enlarged sterile involucres were borne on longer pedicels and were of a lighter and more greenish color, while the small involucres that produced bolls retained the deep reddish purple color of the Upland parent. A similar inequality in the size of the bracts and the elongation of the petioles was found in another perjugate hybrid between Mit Afifi and Triumph, as shown in the left-hand figures (*A*) of Plate II. In this case there was no difference in color, but the enormous development of the bracts of the sterile involucres, with their coarse texture and long incurved teeth, afforded a striking contrast.

If these abnormalities be considered as examples, intensification may be said to abound in the later generations of hybrids as well as in the first. But in the later generations intensification is no longer accompanied by increased vigor and fertility. It is more often combined with weakness and sterility. The vigor of hybrids does not seem to depend merely on the fact that different characters are present in transmission, but rather on some factor of tension or stress involved in the expression of divergent or contrasted characters. It is easy to understand that the expression relations of the characters would not be the same in the first generation, before the protoplasm derived from the diverse parents has completely united, as in later generations, after the protoplasm has passed through one or more complete conjugations. To make the heterozygote class of the second generation equal to that of the first it would be necessary to assume an absolutely complete segregation of the characters which even the typical examples of Mendelism do not indicate. The final result of crossing the different types is not a constructive improvement or combination of characters but a destructive disturbance of the normal processes of heredity.

It is true that natural species are often found with characters more or less intermediate between those of other species, and many writers have inferred from this fact that hybridizing is one of the natural means of producing new species. But there is very little in the way of direct evidence for the production of new species or even stable varieties by hybridization. The few cases where apparently constant forms have been secured by crossing different species are more reasonably ascribed to peculiarities of reproduction such as parthenogenesis, polyembryony, or amitapsis, or to the exclusive survival of embryos that represented certain combinations of characters. Investigators of Mendelian hybrids have reported cases where one of the homozygote classes failed to develop. If both of the homozygote classes disappeared the heterozygotes would be left as an apparently stable intermediate group.[1]

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[1] See Castle, W. E., and Little, C. C., "On a Modified Mendelian Ratio among Yellow Mice," Science, n. s., vol. 32, p. 869.

When hybrids do not breed with each other but are allowed to cross back on one of the parental types the effects of degeneration are not so obvious. The degenerative tendencies that are manifested when the hybrids are bred among themselves are partly counteracted by the effect of the stimulation obtained by crossing with a pure type. This difference was noticed many years ago by the German botanist, Berthold Seemann.

In writing of the inhabitants of the Isthmus of Panama, Seemann made the following statement:

> They [the half-castes] are weak in body and are more liable to disease than either the whites or other races. It seems that as long as pure blood is added the half-castes prosper; when they intermarry only with their own colour they have many children, but these do not live to grow up, while in families of unmixed blood the offspring are fewer, but of longer lives. As the physical circumstances under which both are placed are the same, there must really be a specific distinction between the races and their intermixture be considered as an infringement of the law of nature.[1]

Similar results have been secured in a series of experiments with dilute cotton hybrids. When a pure type, Egyptian, Hindi, or Upland, is crossed with a hybrid the resulting progenies are much more diverse than the first-generation hybrids between the same types. Plants representing only one-quarter of Upland or Hindi blood and three-quarters Egyptian often depart more widely from the normal Egyptian characters than any of the half-blood hybrids in the first generation. The tendency to intensified or extraparental expression of characters in second-generation hybrids is also manifested among the dilute hybrids. Taken as a whole, the dilute or quarter-bloods produced by crossing the hybrids back on one of the parent stocks are distinctly superior to the second generation of the hybrids. At the same time they are distinctly inferior to first-generation hybrids because of the many aberrant individuals. Their status may be described as intermediate between the first generation of ordinary hybrids and the second generation.

If it were necessary to breed from the hybrids, it would evidently be better to combine them with the parent varieties than to breed them with each other, as Seemann inferred. With cotton, however, there is no occasion to use hybrids for breeding in view of the fact that the later generations are inferior to the first. By crossing hybrids of the second or later generations back on one of the parent stocks it might be possible to secure some superior individuals, perhaps as good as first-generation hybrids, but the greater diversity would bring the average far below the first generation. This disparity seems to be less with corn hybrids than with cotton. Nor is it obvious as yet in the series of bovine hybrids produced by Mr.

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[1] Seemann B. Narrative of the Voyage of H. M. S., *Herald,* vol. 1, 1853, p. 302.

A. P. Borden, of Pierce, Tex., between several American and East Indian breeds.

If it became possible to apply vegetative methods to the propagation of cotton, the dilute hybrids might be worthy of further attention, since they afford a means of combining two of the effects of hybridization—vigor of growth and intensification of special characters. That hybrids may be grown from cuttings was shown at Bard, Cal., in the season of 1911. The plants thus obtained were very vigorous and productive, and the bolls were even larger than those of the overwintered parent individuals from which the cuttings were taken and also larger than those of other first-generation hybrids raised from seedlings, as shown in Plate III. The two bolls at the top of Plate III represent the parent plant, the others a plant grown from a cutting.

INTENSIFIED CHARACTERS IN SELECT STRAINS.

Darwin and many later writers have ascribed to selection a more active power of producing changes of characters than the facts of breeding seem to justify. The improvements effected by breeders are supposed to represent changes of the same nature as those that lead to the evolutionary development of new characters. In reality, however, the analogy is not complete. The difference becomes apparent when the nature of the processes is more carefully considered.[1]

The breeder who works through selection alone does not undertake to change the characters of any particular plant or animal. Selection is merely a way of making use of differences that are found already in existence. The lines of descent that show the highest expression of a desired character are preserved and propagated, the other lines discarded. To replace inferior lines by superior lines is a practical improvement quite independent of any change of characters in the select individuals or their descendants. Selection maintains the expression of the preferred characters at a higher average because the inferior lines are eliminated and no longer figure in the average. Such changes are mathematical instead of biological and afford no reason for supposing that selection has in itself any power to create new characters or even to alter expression. The breeder finds superior individuals and uses them to propagate a superior group. Selective improvement is a process of substitution of groups, not of transformation of characters.

The skill of the breeder lies in his ability to distinguish minute differences and thus to separate more successfully the lines of descent that show the largest and most uniform expression of the desired characters. It may be easier to find the desired type by a careful following of the lines of descent than by wandering at random through an endlessly diverse population. The skillful breeder may secure more striking and valuable results with relatively small numbers than less discriminating observers would obtain from much more extensive material. Some breeders begin by hybridizing to induce a wider range of variation than the natural groups afford, but many of the variations shown by hybrids can be found in the parent stocks if a thorough search be made. Hybridizing is of doubtful value with an open-fertilized, seed-propagated plant like cotton, because of the greater difficulty of securing uniform expression of characters after hybridization has occurred.

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[1] Cook, O. F. Methods and Causes of Evolution. Bulletin 136, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1908.

Without ascribing to selection any direct effect in changing characters, the possibility that some changes may be induced indirectly should be recognized. The methods of propagation that are applied to select groups may be responsible for some of the results that have been ascribed to selection. Selection is usually accompanied by restriction of descent to a few ancestral lines. The range of crossing is narrowed more and more as selection becomes more discriminating and efficient, until the method of pure-line breeding is reached. This calls for the narrowest possible limitation of ancestry, by in-and-in breeding or self-fertilization.

The chief object of restricted descent is to secure a uniform expression of desirable characters in the progeny, but this is not the only effect of narrow or line breeding. The evil results that often arise from consanguineous marriages have been recognized since very early times and by very primitive peoples, and similar results are known to follow with many species of plants and animals. Inbred strains are preserved only by persistent weeding out of degenerate individuals.

Two principal kinds of injury from narrow breeding may be distinguished, though they are likely to be found together. One is a lack of constitutional vigor, usually manifested in smaller size or diminished resistance to disease or to unfavorable conditions. The other is an increase or intensification of any abnormal feature or tendency of the parents.

Any lapse from normal heredity in the parent is likely to be repeated in at least a part of the descendants. Thus, the Arabs of Palestine consider it undesirable to breed from a horse having any of the skin white, however small the area, for they say that the spot is likely to be much larger in the foal. The tendency of any abnormal characteristic to reappear is greatly increased when it is represented in the heredity of both parents, which is more likely to occur when narrow or line breeding is being practiced. Albinism and other changes of color are among the most frequent of these degenerative variations that appear in groups subjected to narrow breeding.

When one of the degenerate variations of a select stock happens to coincide with an object that is being sought by breeders it is only natural to look upon the result as a direct effect of selection. A seedless apple or other degenerate variation is likely to be hailed as a triumph of selection, even when there has been no attempt to produce that particular variation. The chances of securing such a variation as seedlessness can be increased, no doubt, by propagating from individuals that have fewer seeds, but the increase of the abnormality in any particular individual can hardly be ascribed to selection. The steps have to be taken by the plants themselves, not by the operator. All that can be done is to find a seedless individual and propagate it from cuttings.

The truth is that we have no means of causing any desired variation to appear, by selection or otherwise. All that we can do is to take advantage of the general fact that variations do appear and seek for the most desirable. There are ways of inducing variation by changing the environment, by crossing, or by degeneration through narrow breeding, but these methods do not assure us of any particular result; they only increase our chances of finding what we want. As in throwing dice or dealing cards, the chances are against any particular combination being formed in any limited number of cases. The larger the number of combinations the greater chances that some of them will prove desirable. Selection is the art of finding the combinations after they have occurred, but it is not the art of making combinations. That more desirable combinations or degrees of expression may appear in selected stocks is not to be ascribed to selection, except indirectly, in the same way that the undesirable, degenerate variations must also be considered as results of the condition of inbreeding that selection induces. The undesirable variations are vastly more numerous than those that are superior or even equal to the parental type.

Whether losses of color or of other normal characters represent simply failures of expression or more deep-seated injuries of the mechanism of transmission is not known. The Mendelian inheritance of such variations has been taken as proof of alternative transmission, but alternative expression serves as well to explain the mathematical relations of Mendelism and also accounts for the frequent cases of reversion or reappearances of characters, even after they have been suppressed for many generations. To explain reversion, Mendelian writers have suggested that such characters may be due to two or more factors that have been transmitted separately and then reunited by crossing. But this factorial explanation of latency can hardly be brought into action when reversions take place without crossing. Recourse must then be had to the idea that the character or factor has been recreated as a mutation.

The fact that so many of the differences between select varieties show Mendelian inheritance may be taken to indicate that the suppression of characters is a very frequent occurrence among our domesticated animals and plants. Similar variations occur, of course, in wild species, but they seem to be much more rare, and seldom able to persist. The white, black, brown, or yellow colors that distinguish the domesticated varieties of mice, rats, guinea pigs, or rabbits, the characters that afford the materials for so many Mendelian experiments, are not paralleled by any corresponding differences among the related wild species. It is the same way with plants. The cultivated varieties differ largely by the absence of some of the characters that all of the wild types have. Thus no wild or unselected stocks of cotton are known to have the shortened "cluster" type of fruiting branches, which represents one of the most frequent of mutative variations of select strains.

The differences that distinguish natural species are not like the sharply contrasted unit characters that distinguish mutations, but are of a much more general and indefinite nature. Nor do hybrids between natural species vary in the same definite ways as hybrids between select, uniform varieties. Instead of merely different combinations or intermediate expression of the characters of the parent individuals, interspecific hybrids generally show a much wider range of variation, both above and below the standards of the immediate parents.

It usually takes several generations of domestication for wild species to break up into various colors and other varietal differences, but when these changes occur they often follow remarkably parallel lines. It is possible, apparently, to secure cluster variations in any type of cotton that is subjected to selection. The same tendency to abnormal shortening of internodes also appears in many other plants, as witness the "bush" varieties of squashes, peas, and beans.

Aberrations of color characters are frequent in plants as well as in animals. They are usually confined to the flowers, though variegated leaves also occur, probably in all the families. Complete albinism is an impossibility among the higher plants, because the albino individuals starve to death in the seedling stage as soon as the supply of nourishment stored in the seed is exhausted. The absence of chlorophyll prevents the formation of starch and thus inhibits development. Yet many albino seedlings have been seen, both in cotton and corn. In such cases it is certain that the variation is not in the nature of a reversion, for no albino ancestor could have lived or produced seed.[1]

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[1] That albino plants would be able to live and reproduce like albino animals, if they could nourish themselves, was indicated by an instance, called to my attention, at

It has to be recognized, therefore, that domesticated plants and animals are subject to certain forms of negative variation, representing losses or suppressions of characters. The progressive increase or intensification of a negative, degenerative character under conditions of selection should not be mistaken for a positive, constructive development of a new character. The possibilities of selection are by no means the same in the two cases. Lintless varieties of cotton would be very easy to develop by selection, for all types of cotton show frequent variations toward reduction of lint. Even without any such selection, plants with no lint at all have appeared. All the selective effort has been applied to the increase of the length and abundance of lint, and yet no marked increase or intensification of these characters seems to have occurred. Unselected Mexican and Central American varieties of Upland cotton have lint as long or longer than any corresponding varieties in the United States.

There are hundreds of inferior mutations with short or sparse lint to one that is superior to the parental type, or even equal. Though continued selection is necessary to preserve the uniformity of varieties of cotton and maintain the length of the lint, there is nothing to show that selection can produce further elongation. It is no more reasonable to say that variations toward longer lint are caused by selection than to say that selection has caused the much more frequent variations toward short or sparse lint. If the question were to be decided by an average of the variations in comparison with the parent stock, the conclusion must be that selection has an adverse effect.

The idea that it is possible by dint of selection to induce new variations in any desired direction undoubtedly has served as a great encouragement to breeders. It is responsible for some brilliant successes in finding superior types, and also for some costly failures, where something was sought that perhaps did not exist. If a desired change is in the nature of a suppression or breaking down of a normal coordination or specialization of parts, the conditions of selective inbreeding may be expected to favor the increase or intensification of such a negative or degenerative variation. But if a positive character is required, such as an increase of vigor or fertility, or

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Somerton, Ariz., in July, 1909, by Mr. Rowland M. Meade. This was an albino bud mutation of a watermelon vine that grew out into a large branch several feet long, supported, no doubt, by its attachment to the green parent plant. All of the vegetative parts of the albino branch were pure white. The leaves were never fully expanded like those of the normal branches. The albino branch bore a single fruit in October, about 8 inches in diameter and of a short oval form. The rind was a very pale yellowish green, somewhat blotched with slightly darker greenish, but still quite pale. The flesh was pale greenish under the skin and pale pinkish within, with a solid white center. The taste was insipid and disagreeable. The seeds were saved to see whether they would germinate and produce albino seedlings, but were accidentally lost. The presence of the green color in the fruit may be taken to indicate that this character did not cease to be transmitted, though it had failed to appear in any of the vegetative parts of the branch.

the largest expression of some special feature or of a specialized organ or function, the task of selection is to find the superior type and then to maintain a uniform stock by removing all defective individuals. Selective inbreeding seems to intensify only the negative characters. Positive characters are intensified by crossing.

INTERMEDIATE EXPRESSION OF METAMERIC DIFFERENCES.

Abnormalities are of interest in the study of heredity. To understand what happens when the mechanism of heredity becomes deranged is to gain a better idea of the normal processes. Our knowledge of the functions of the internal organs of the human body has been gained very largely through the study of diseased conditions. Many kinds of abnormalities have been described and classified, the study of such phenomena being recognized as a special branch of biological science, called teratology.

One type of abnormality of very frequent occurrence in the cotton plant may be ascribed to an intermediate expression of characters that normally distinguish the different kinds of metamers or internodes that make up the bodies of plants. With many plants a section of the stem with its leaf or leaves may be capable of an independent existence, as in the case of the cotton plant. The change of characters required in passing from vegetative to floral parts is normally quite abrupt. When there are only partial or gradual changes of such characters the results appear abnormal.

In all normal cotton plants the leaves of the fruiting branches and the bracts that compose the involucres of the flowers are entirely different structures, quite unlike in size and shape, as may be judged from a comparison of figures 3 and 4. But cases are often found where the normal specializations of leaves and bracts are not reached and abnormal organs appear, representing intermediate stages between leaves and bracts (fig. 5). In some of the bractlike leaves the petiole is only partly suppressed (fig. 6). It often happens that the two sides are unequally affected, the petiole being suppressed on one side but not on the other. One stipule is united with the blade while the other is separated, often for a considerable distance. Such leaves are often distorted, or even torn, by the unequal growth of the two sides, as in the example shown in figure 7. Sometimes there is a reduction in the size of the leaf without a change of form or texture (fig. 8).

In leaflike bracts the form and texture may be normal, but without a proper union of the parts (Pl. IV). Or the parts may be properly united at the base and yet lack the normal specialization of marginal teeth (fig. 9). Sometimes the middle division, representing the blade of the leaf, is much longer than the lateral divisions that represent the stipules (fig. 10).

Such failures of the mechanism of heredity to maintain the normal contrast between leaves and bracts are usually accompanied by an inability to produce the normal structures of the flower and fruit. The flower buds of abnormal involucres are usually aborted. Sterility seems to accompany an intermediate expression of characters in the parts of the individual plant, as well as intermediate expression in hybrids between remotely related species.

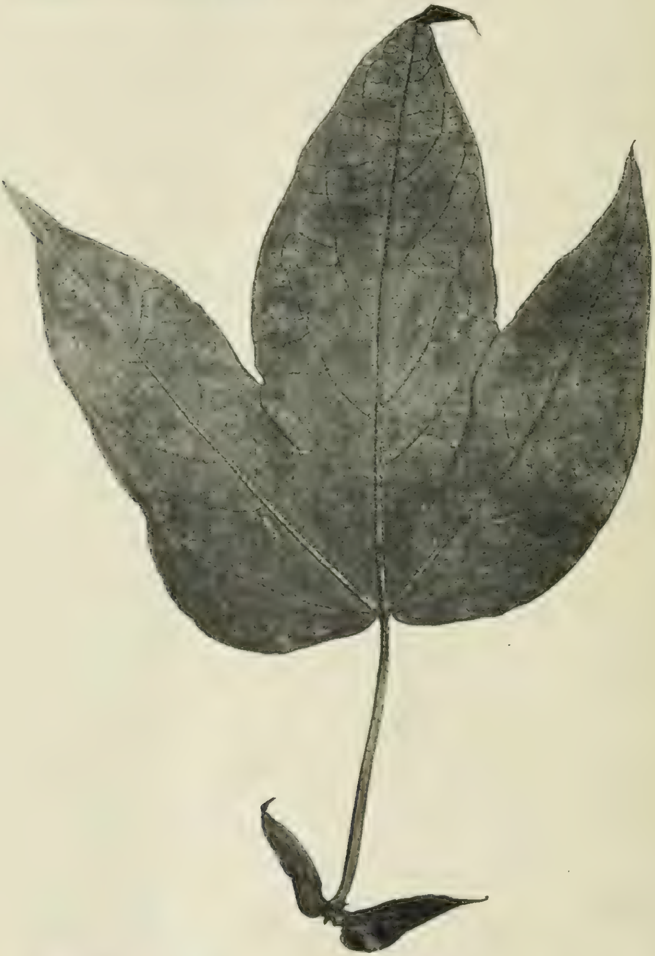

FIG. 3.—Leaf of fruiting branch of Egyptian cotton. (Natural size.)

The whole series of "cluster" varieties of cotton shares the tendency to abortion of the buds. The cluster habit represents a failure of the normal differentiation between the internodes of the fruiting branches and those that form the pedicels and involucres of the flowers. The branch internodes are shortened as well as the floral internodes. The leaves of such branches are more bractlike, while the bracts are more leaflike. Intermediate forms of leaves and bracts are much less frequent in the Upland type of cotton than in the Egyptian, but sometimes occur (fig. 11). Deeply divided involucres are often met with in cluster varieties (Pl. V).

Though such losses of normal specialization usually occur as definite mutative changes of characters, there are also indefinite variations of the same kind. The outer bract of the involucre often has an intermediate form while the others show the normal specializations (fig. 12). These cases are of interest as evidence of a power of spontaneous readjustment in the mechanism of heredity. A fruiting branch that has produced an abnormal internode may afterwards produce normal internodes. An example of this is shown in Plate VI, which represents leaves from three successive internodes of a fruiting branch of Egyptian cotton. The first leaf is of the normal form, with a 3-lobed blade and small stipules. The second leaf has one of the stipules distinctly enlarged and bractlike, while the blade is simple. The third leaf is like the first, with normal, 3-lobed blade and with the stipules only slightly enlarged.

A power of readjustment is also shown when normal flowers, fruits, and seeds are produced in connection with abnormal leaves and bracts. In one Egyptian variety called "Dale," as grown in California, nearly all of the bracts and leaves of the fruiting branches are abnormal. This variety is also subject to wholesale abortion of buds and bolls. Yet most of the plants are able to produce small crops of seed.

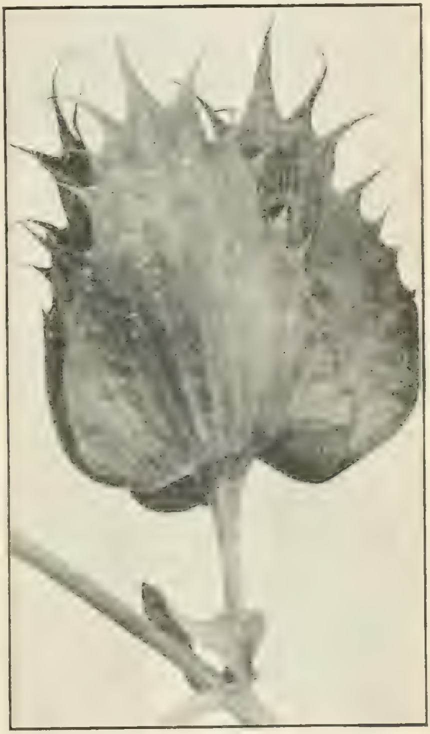

FIG. 4.—Involucre of Egyptian cotton with normal bracts. (Natural size.)

Another class of metameric hybrids is shown in intermediate expressions of the characters of the two types of branches. The abnormal fruiting branches, instead of being slender and horizontal, keep a more upright position and become thicker than the others. Such branches usually abort all of their buds. When bolls are produced they are usually small and misshapen and have many abortive seeds. Plants that fail to develop normal fruiting branches have a more upright fastigiate habit of growth and usually become taller than other plants in the same rows. At Del Rio, Tex., in September, 1911, it was noticed that abnormal plants in the Durango variety usually had greener stems and bracts than normal plants and either coarser or finer teeth on the bracts. But some of the abnormal individuals that had most of the bolls and seeds abortive had longer and stronger lint than normal plants in the same rows. This could be ascribed, at least in part, to the fact that very little fruit was produced. Plants that bear a small crop are less liable to checking by drought or other unfavorable conditions.

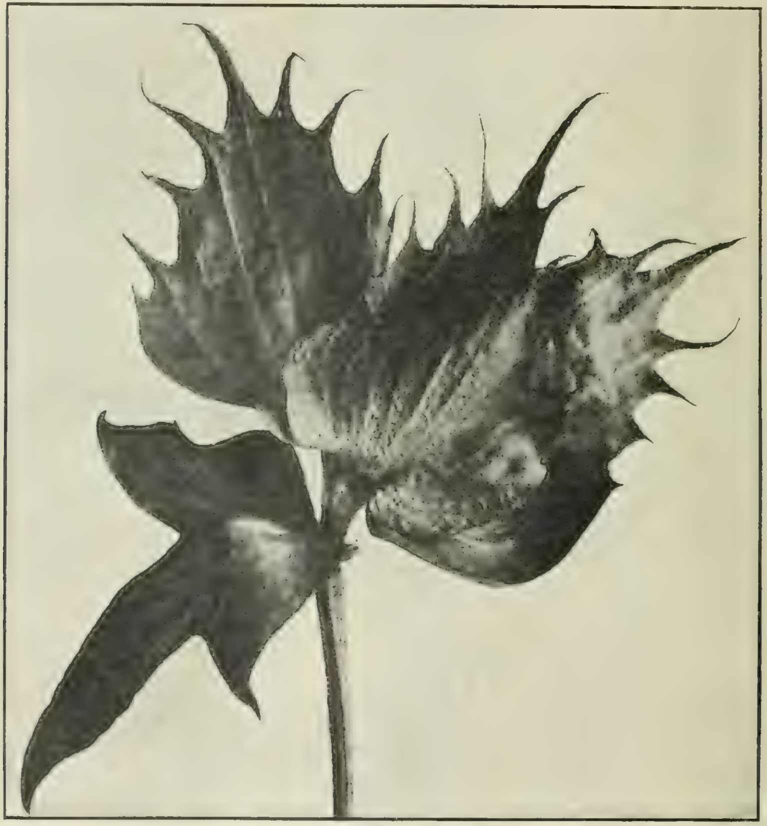

FIG. 5.—Abnormal bractlike leaf of Egyptian cotton subtending a nearly normal involucre. (Natural size.)

The occurrence of abnormal branches, internodes, leaves, or bracts is not a matter of scientific interest alone, but is to be considered in selection. It becomes possible to judge by careful inspection of a plant whether its expression relations are definite and well established or liable to vary. Indications of uniformity may be given by the many internode individuals of a plant as well as by the individual plants of a progeny row. Thus at Bard, Cal., in the season of 1911, a plant of Egyptian cotton with numerous abnormal bracts but no other obvious divergence from the characters of the Yuma variety was found on closer examination to have seeds much like the Hindi cotton. There was no fuzz, and the lint retained the length and color of the Egyptian cotton, so that it would have been easy to overlook the other differences if the abnormal bracts had not been noticed.

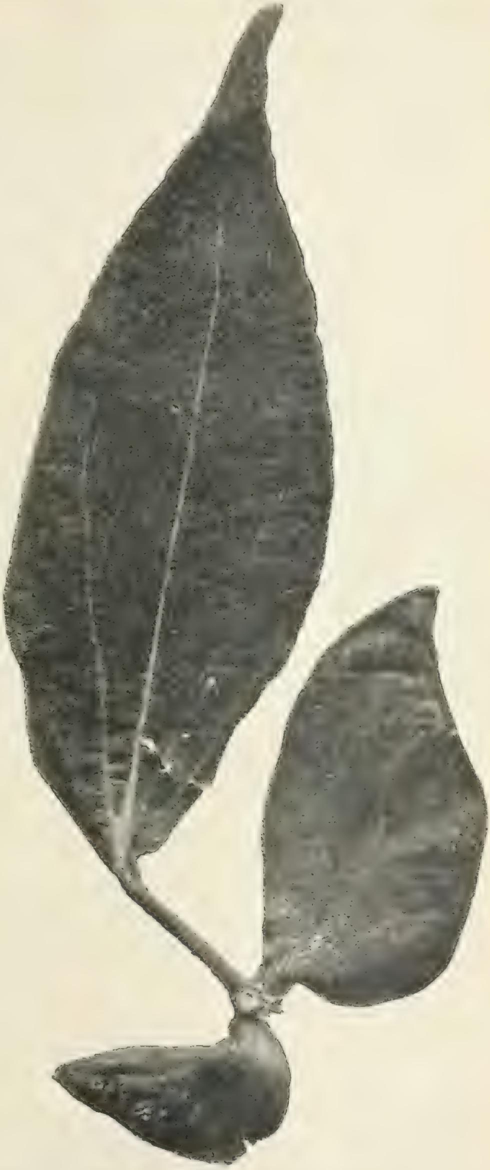

FIG. 6.—Bractlike leaf of Egytian cotton, with the blade and petiole reduced and the stipules enlarged. (Natural size.)

SIMULTANEOUS CHANGES OF EXPRESSION OF DIFFERENT CHARACTERS.

The emphasis given to the idea of characters as independent units tends to obscure another fact of general importance in practical breeding. Independent transmission of characters implies the occurrence of definite variations in single characters, leaving all the other features the same. In reality, such independent changes of single characters occur very seldom, if at all.

The nature of the mechanism of expression is such that a definite change in one character usually involves changes in many other characters. A change of expression does not seem to represent merely a choice among many independent units, but a choice among whole sets of characters as represented by different ancestral individuals. A close resemblance to a particular ancestor in one feature is likely to be accompanied by resemblances in other features or traits of character. The descendants form a continuation of the ancestral network of descent, sometimes on the same paths and sometimes on intermediate courses. Each plant or animal has its individual characters as well as its individual experience with the environment. As Goethe said: "Nature knows only the individual."

It may be better to think of characters as paths followed by individual ancestors than to attempt to conceive of them as represented by discrete particles existing in the protoplasm. As a species represents a natural entity, because its members breed together in a network of descent, so the characters of the individual plants and animals seem to have a continued existence because of their repeated expression in the lines of descent. The characters are like the threads of different colors that appear on the surface of a woven fabric, only to be lost again as the pattern changes. The same thread returns, but not the same material. The pattern is repeated, but on another part of the cloth. The pattern is only a method of arranging the material. Apart from the fabric itself, there may be nothing to represent the pattern, except the design in the mind of the weaver.

Uniformity among the members of a variety means that each individual follows the same course of development. If any individual wanders from the path with respect to one character it is more likely to continue on a different route during its subsequent development. There is a sequence in the determination of the characters, the expression of one character constituting a more favorable or less favorable condition for the expression of another. With characters standing in such relations to each other, it is easy to see why correlations, coherences, and simultaneous variations should occur. No such flexibility of expression relations would be expected if the characters were independent units, to be varied only by alternative transmission.

That the permanence of ancestral traits should suggest the idea of characters as separate entities is easy to understand on the basis of physical analogies. But notwithstanding the antiquity of the idea of independent character units, no direct evidence of the existence of such entities has been adduced. Instead of being a discovery of modern science this idea may be traced back far beyond Weismann and Darwin to the evolutionary theories of the Sicilian Greek philosopher Empedocles and his Roman disciple Lucretius. These ancient writers described the parts of animals as originating independently and afterwards finding harmonious combinations by a process of gradual adaptation. The idea was doubtless suggested by the mythical monsters whose existence was credited in ancient times: Centaurs, satyrs, cyclopes, hippocampi, bucephali, etc.

Our modern theories do not contemplate the combination of characters of such radically different types, but they give us no better reasons for holding that characters are separate entities. The ancient and modern theories are also alike in failing to take into account the existence of species, and the normal diversity of members of specific groups. With such an inheritance of diversity it seems to be easier to vary in several characters at once than to change the expression of one character without disturbing the others.

It is convenient for many scientific purposes to describe and discuss characters as though they had an independent existence, in the same same way that navigators treat the lines of latitude and longitude, but the convenience of such analogies affords no assurance of actuality. As well might we expect to find the geographical parallels marked by rivers or mountains. Any analogy that aids investigation is justified by the assistance it affords, but scientific progress is often hampered by holding too long to misleading analogies. It may be that we can form no conception of the workings of heredity without some theory of characters as localized particles, but neither has it been possible to frame any adequate conception by assuming the existence of such particles. To maintain and arrange the particles would require some very effective agency of coordination which no system of independent, separately transmitted units would supply.

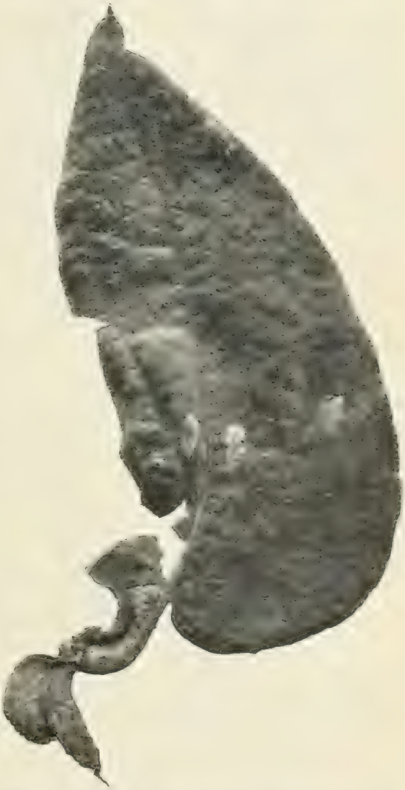

FIG. 7.—Bractlike leaf of Egyptian cotton, with the stipule united to the blade and the petiole suppressed on one side but not on the other. (Natural size.)

Whatever may be the cause of simultaneous changes of expression relations, it is of practical importance in agriculture to recognize the fact and use it as an aid in detecting and eliminating variations that would otherwise destroy the uniformity of select stocks. The agricultural value of superior varieties of cotton and many other agricultural plants depends upon the possibility of maintaining uniformity through many generations. It is quite as important to preserve the uniformity of superior varieties as to develop such varieties in the first place. Indeed, it may be worse than useless to develop and distribute highly selected types of cotton if uniformity is not to be preserved by continued selection, for the degenerate variations of highly bred stocks often fall below the average of ordinary varieties.

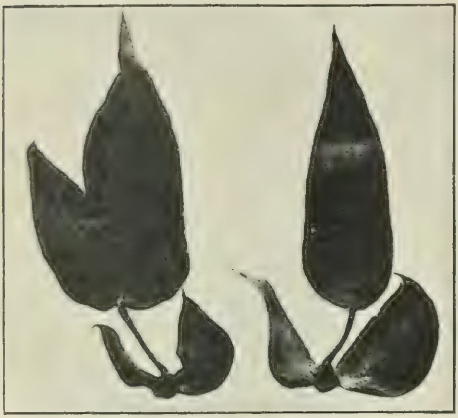

FIG. 8.—Bractlike leaves of Egytian cotton, reduced in size but only slightly modified in form. (Natural size.)

If each character were at liberty to change independently, the elimination of variations from select stocks would be a well-nigh hopeless undertaking, but the fact that many characters vary together makes it much easier to detect and rogue out the mutations as soon as they appear. For the purposes of Mendelian experiments the existence of varieties differing by only a single character is often assumed, but this has reference to characters with contrasted Mendelian expression, other kinds of differences being disregarded.

The apparent utility of the theory of character units depends largely on the assumption that there are only a few, so that they can all be analyzed by the breeder and separated in pure strains. But in reality the contrasted differences that may be found in a series of hybrids or mutations are extremely numerous. Thus, in cotton there seems to be an apparently endless series of characters that could be formulated on differences of size, shape, position, color, texture, hairiness, and glandular equipment of the various parts of the plants. The largest and most varied series of such differences have been found in progenies of self-fertilized hybrids. According to Mendelian expectations, these should fall into classes characterized by definite distributions of the parental characters, but most of them show characters far outside of the usual range

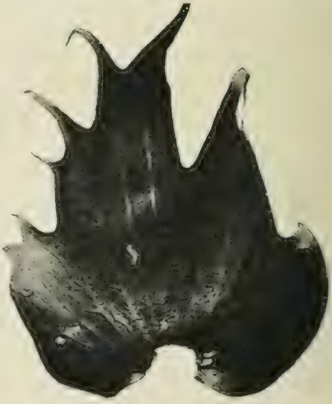

FIG. 9.—Leaflike bract of Egyptian cotton, with the blade and stipules not completely united. (Natural size.)

of variation of the parental types. Some of the bolls are longer and narrower than in either of the parent types (figs. 13 and 14) and some are shorter or broader (fig. 15). Equally striking variations occur in the involucral bracts. In addition to many other differences of size, shape, texture, color, and marginal teeth, the positions of the bracts are extremely varied. Some plants have the bracts closely appressed to the bolls (fig. 16), while some have them inflated and standing away from the bolls (fig. 17). Another peculiarity is the twisting of the bracts to the side. There is a slight tendency to twisting in the Egyptian cotton, but in some of the hybrids it becomes very striking (fig. 18).

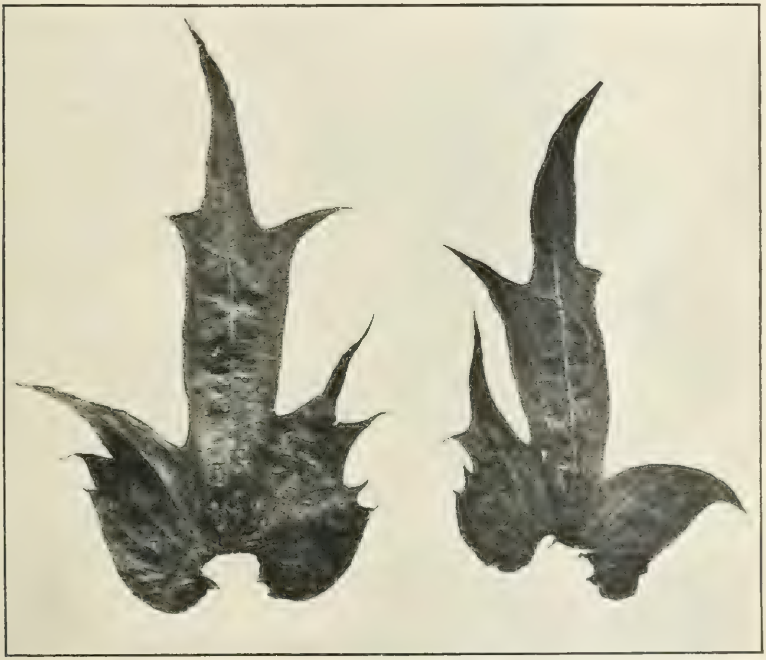

FIG. 10.—Leaflike bracts of Egyptian cotton, with the blade much longer than the stipules. (Natural size.)

Though such hybrids are of no value in themselves, the study of their diversities may aid in the recognition of the less frequent but perhaps equally varied mutations that appear in select stocks. The persistence of the student will determine how many of these variations shall be recognized and described. The descriptive task can be simplified, of course, by confining attention to the extreme forms of variation, but it is no less important to recognize the intermediate members of the series.

In the improvement of the cotton crop, where uniformity of fiber is a primary consideration, the recognition of this principle of simultaneous change of expression of many characters is especially important. It enables most of the mutations to be detected early in the season before they have reached the flowering stage. Otherwise they furnish pollen for infecting the seed of their neighbors, with the tendency to degenerate variation. Selection applied at the end of the season is much less effective.[1]

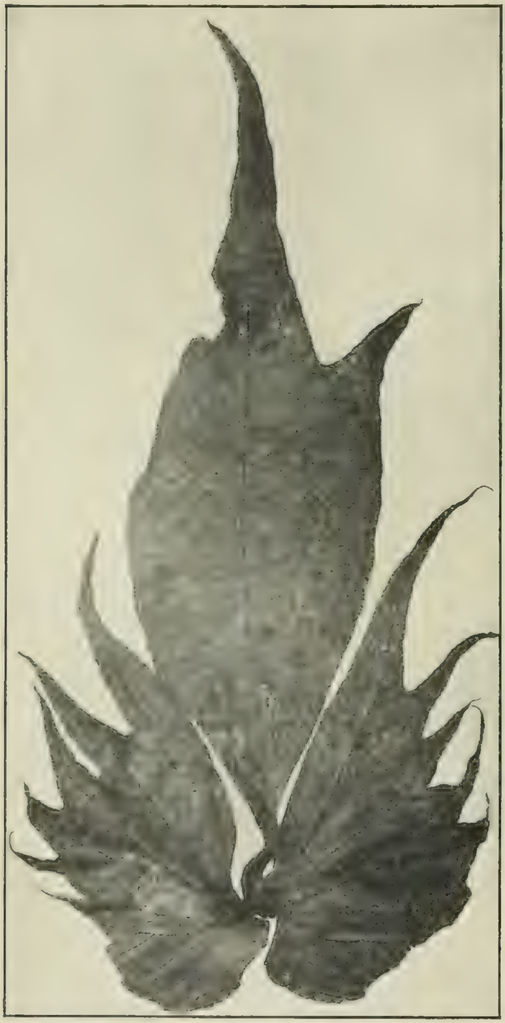

FIG. 11.—Bractlike leaf of Willet Red Leaf variety of Upland cotton. (Natural size.)

Though mutative degenerations can usually be detected by observing the lint and seed characters, it is a much easier method, as well as more effective, to recognize them from the external vegetative characters of the plants. An example of the extent to which mutations often differ from the parent type in lint characters is shown in figure 19, where three seeds from a degenerate mutation are compared with two seeds from an adjacent normal plant in a field of the Lone Star variety at Waco, Tex., in the season of 1911. Though the seed differences are obvious enough when the lint is combed out, this would be unnecessary in actual practice, for the plants that produced the inferior lint could be distinguished from the Lone Star type by simple inspection in the field. For a farmer sufficiently familiar with his variety, the removal of such plants would take no more time than pulling an equal number of weeds and would be much more important for the welfare of the crop.

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[1] Cook, O. F. Cotton Selection on the Farm by the Characters of the Stalks, Leaves, and Bolls. Circular 66, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1910.

DIFFERENCES AND SIMILARITIES OF MUTATIONS.

That mutative variations should differ from the parent variety in many respects rather than in only one or two characters is easier to understand when we remember how the condition of uniformity is attained—by the suppression of the normal individual diversity of the ancestral stock. As the mutations that arise in select strains of cotton show the same general range of diversity as the members of unselected stocks, it does not seem surprising that the mutations should differ from each other and from the parent type in many characters, like the individuals of normally diverse groups.

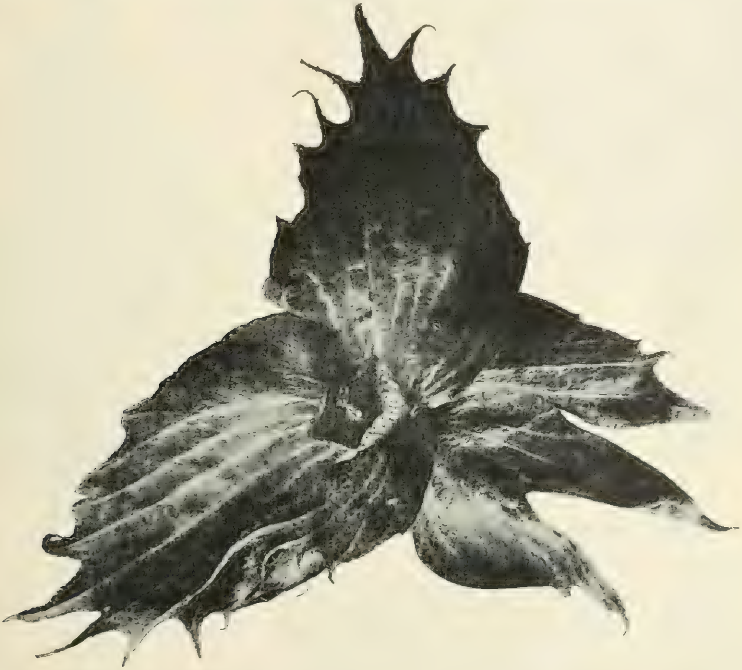

FIG. 12.—Involucre of Egytian cotton, with outer bract of intermediate form and the others nearly normal. (Natural size.)

In addition to a wide range of diversity among the mutations of the same stock, it is also necessary to recognize cases of closely similar or parallel mutations, like those that have been taken by De Vries and other recent writers as examples of evolutionary change in definite directions. Yet there is no reason to expect that mutations, any more than other variations, should differ indiscriminately or show mere random combinations of characters. Observation of many mutations of cotton and other plants indicates that the general laws of correlation or coherence in the expression of the characters apply among mutations as well as among hybrids and among the normal individual diversities of unselected stocks.

As already noted, the single set of characters shown by each of the many members of a variety corresponds to the equipment of a single individual in a normally diverse group, like the human species. Individual men and women do not differ by single characters or by merely random combinations of characters, but show large series of coordinated differences. The fact of correspondence or interrelation between the different characters of the same individual has been recognized by the great French sculptor Rodin, the competence of whose opinions on the characteristics of the human form will scarcely be questioned. In a recent criticism of the method of constructing ideal human forms by combining characters from different models emphasis is placed on the perception of correlations of characters as an essential of artistic ability and taste. Rodin's views are reported as follows:

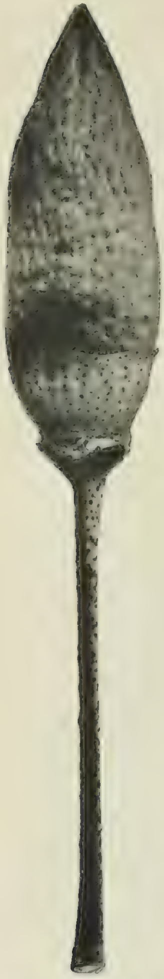

FIG. 13.—Boll of Egyptian-Hindi hybrid, showing extreme variation toward narrow oblong form. (Natural size.)

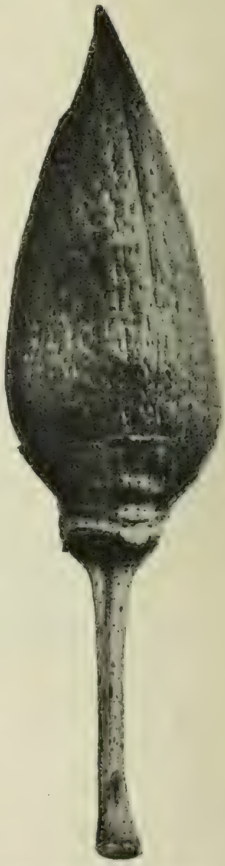

FIG. 14.—Boll of Egyptian-Hindi hybrid, long, tapering form. (Natural size.)

> Everything in nature is beautiful for the real artist, for the man of imagination. Nothing is more ridiculous than the effort of an artist to produce something beautiful, something perfect, by combining perfect parts of different models into one. Thus the artist who reproduces the eyes of one model, the hands of another, the feet of a third, the neck of a fourth, produces perhaps a beautiful doll, but it is lifeless and worthless.
>
> There is no such thing as ugliness in nature, in life. Everything is beautiful if seen through the artist's mind. The imperfections become perfect. There is nothing more wonderful than life.[1]

To bring together characters that do not form natural combinations is unpractical for the breeder as well as inartistic for the sculptor. When incongruous combinations of characters occur in cotton hybrids the plants are usually defective or infertile. Many attempts have been made to combine the superior lint of the Egyptian cotton with the superior cultural characters of the Upland cotton, but thus far without success. In the rare cases when plants are actually obtained that combine some of the distinctive features of two types, such as Upland habits of growth and Egyptian flowers or Egyptian vegetative characters and Upland flowers, such plants are likely to produce little or no seed.

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[1] "Rodin on the Crisis of Sculpture." Literary Digest, vol. 43, no. 4, 1911, p. 139.

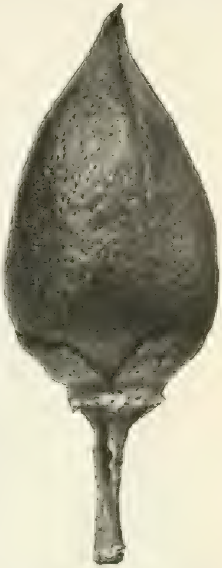

FIG. 15.—Short, broad form of boll of Egyptian-Hindi hybrid. (Natural size.)

Though mutations and hybrids can often be separated into distinct classes based on the presence or absence of the more definitely alternative characters, they may have a wide range of individual differences in other respects. The diversity manifested in mutations is like the diversity of hybrids, except that the progenies of mutations usually show a much more stable expression of characters. If desirable combinations of characters are found in mutations, they are much more easily preserved than in hybrids. The fact that most of the mutations are degenerate and worthless should not be allowed to obscure the importance of discovering the rare examples of superior mutations to serve as parents of new varieties.

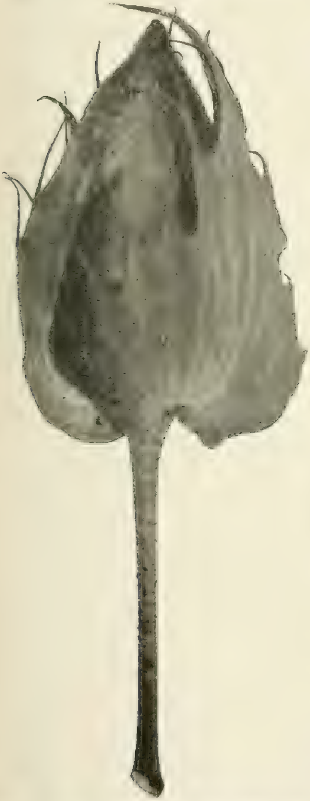

FIG. 16.—Involucre of Egyptian-Hindi hybrid, with appressed bracts. (Natural size.)

Familiarity with the plants gives the practical breeder something that the statistical expert may not have—an ability to recognize desirable plants by direct perception. A skillful breeder has no more need for a score-card system as a guide in selecting a superior plant than a sculptor has for Bertillon measurements in the choice of models.

Most of the mutations of selected varieties of cotton can be described as small-bolled reversions, for they have smaller bolls than the parent variety. Though small-bolled reversions are likely to agree in many other respects, such as narrower leaves, longer internodes, and more upright branches, they are still very far from being duplicates. When the progenies of such plants are raised each row seems to represent a different variety. Small bolls were doubtless the rule in the ancestral stock from which the big-boll varieties were separated by selection. The persistent tendency of cotton to vary toward small bolls may be compared with that of breeds of chickens to vary toward red feathers or sheep toward black wool or corn toward red ears.

A general tendency for narrow leaves to be accompanied by smaller fruits has been observed among mutations of the coffee shrub in Central America. Planters recognize that the narrow-leaved plants produce a larger proportion of berries with only one seed of the rounded "peaberry" or caracolillo form, which formerly commanded special prices. As might be expected from the tendency to abortion of seeds, the narrow-leaved variations do not yield as well as the parental type of ordinary "Arabian" coffee, and they have not become favorites in cultivation.

Another tendency shared by many otherwise different mutations of cotton is toward a shortening of the internodes of the fruiting branches, resulting in the "cluster" type. The shortening of the internodes probably does not represent an ancestral feature or even a positive character at all, but a loss of the normal specialization of parts of the plant, as already stated in a previous chapter. In Mendelian language, this might be described as the absence of a normal or long-joint character replaced by a short-joint character. But the continued transmission of the normal long joint is shown in cases of reversion that appear in cluster varieties, either as individual variations or as modifications induced by environmental conditions.

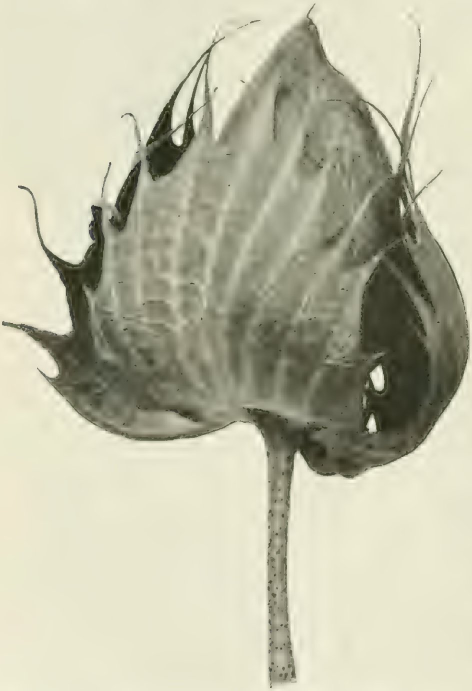

FIG. 17.—Involucre of Egyptian-Hindi hybrid, with inflated bracts. (Natural size.)

The inadequacy of the Mendelian theory that mutative variations are caused by a definite addition or subtraction of character units from transmission has been recognized recently by Gates in the case of a mutation of Oenothera, that gave very frequent reversions to the parent form. The inference is drawn that such changes of characters must be quantitative rather than qualitative. In other words, they can be considered as arising from differences in the strength of the relations that control the expression of the characters rather than because factors of transmission have been added or removed. Gates summarizes his study of this point in the following statement:

> On account of these reversions in *O.* [*Oenothera*] *rubricalyx*, which happen in the first and in all later generations, its origin can not be attributed to the loss of a "factor" or an inhibitor or other substance from the germ plasm. The change has been a positive one just as it appears to be. The Mendelian presence-absence hypothesis, commonly used to explain the numerous cases of Mendelian color inheritance in plants and animals, will not apply here. The difference between *O. rubricalyx* and *O. rubrinervis* is instead a purely quantitative one, *O. rubricalyx* having originated through a quantitative readjustment of the materials of the germ plasm leading to the formation of the substances which determine anthocyan formation as a product of the plant's metabolism. This hypothesis is rendered necessary by the fact that these quantitative differences in capacity for anthocyan production are strictly inherited, notwithstanding the well-known fact that this character is subject to wide fluctuations owing to environmental conditions. It is probable that many cases of Mendelian color inheritance are to be accounted for as the result of similar heritable quantitative differences, rather than by the hypothesis of the presence or absence of certain factors in the organisms.[1]

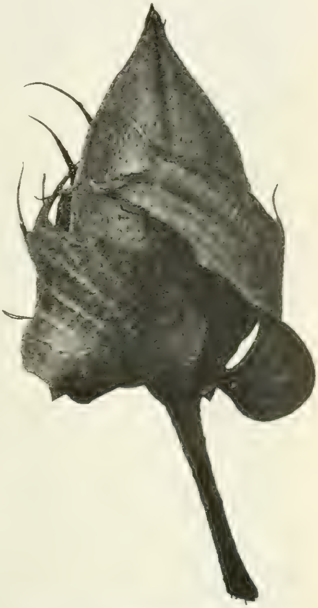

FIG. 18.—Involucre of Egyptian-Hindi hybrid, with twisted bracts.

Selection for extreme earliness and fertility favors abnormal reductions of the vegetative parts. Though such abnormalities would not be likely to survive in nature, they may be valuable in domestication. Under favorable conditions cluster varieties of cotton are extremely productive, but they are easily injured by unfavorable conditions. The crop is often lost by the blasting of the buds, or the quality of the fiber may be injured as a result of premature opening of the bolls.

Thus, the selection of plants that make the very highest yields under the most favorable conditions may defeat the object of securing the most valuable stocks for general purposes of production, just as the persistent selection of fowls with the very highest records as egg producers has been found to yield a relatively inferior progeny. The loss of the instinct of incubation in many different breeds specially selected for laying qualities may be compared with the general tendency to shortening of internodes in selected varieties of plants. Nonsitting fowls would be as unsuited to survive in nature as "cluster" varieties of plants.

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[1] Gates, R. R. Studies on the Variability and Heritability of Pigmentation in Oenothera. Zeitschrift für Induktive Abstammungs und Vererbungslehre, vol. 4, pt. 5, 1911, p. 370.

INTERFERENCE IN EXPRESSION RELATIONS.

The idea that any desired combination of characters can be secured by hybridizing different types of cotton or other plants is in accord with the theory of characters as independent units capable of separate transmission, but the expression relations are left out of account. In some cases it may be possible to combine two desirable characters in hybrids without interfering with the expression of other characters, but such combinations are often prevented. Strong tendencies to coherence in the expression of a group of characters that have come from the same parent interfere with the substitution of contrasted characters from the other parental group. Thus coherence of characters limits the application of the Mendelian theory of heredity in practical breeding.

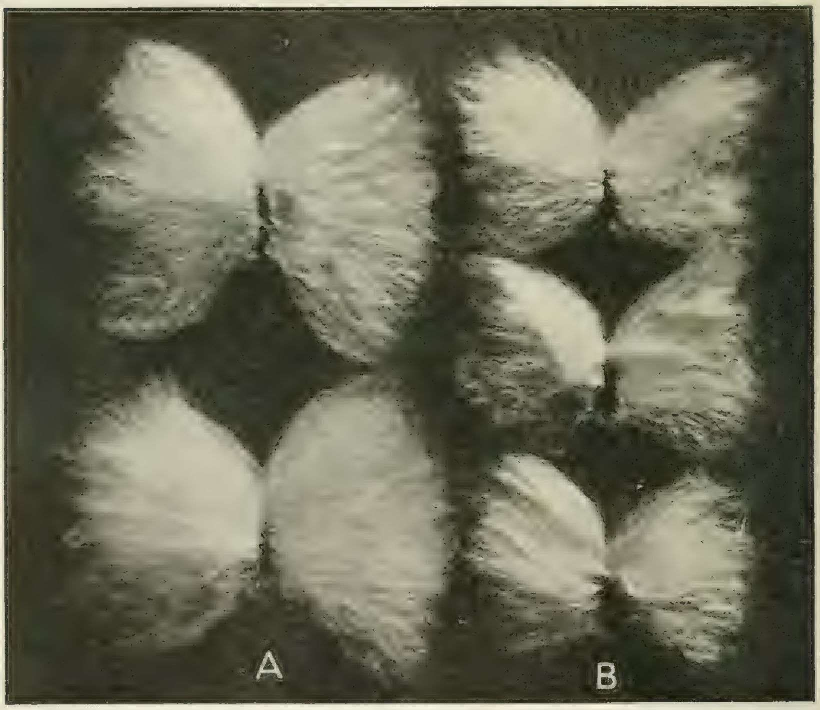

FIG. 19.—Seeds of Lone Star cotton (*A*) and degenerate mutation (*B*), with lint combed out to show comparative length. (Natural size.)

That the characters of plants and animals should combine in definite proportions, after the analogy of chemical compounds, is a very attractive idea and is doubtless responsible for the tendency of popular writers to accept assurances based on the Mendelian theory as demonstrated facts. Statements like the following are frequently found in publications on breeding and eugenics:

> Pure varieties breeding true can be established permanently by taking into account the Mendelian laws of heredity. Similar results have been accomplished in many other plants and in many animals. A cotton has been produced which combines early growth, by which it escapes the ravages of the boll weevil, with the long fiber of the finest Sea Island varieties. Corn of almost any desired percentage of sugar or starch, within limits, can be produced to order in a few seasons. The hornless character of certain varieties of cattle can be transferred to any chosen breed.[1]

The discrepancy between such an assurance and the actual fact is that the crossing of different types of cotton for purposes of forming Mendelian combinations of contrasted characters does not leave them pure or with the same adjustments of expression of the other characters as before. Though the first generation is often equal or superior to the best members of the parent stocks, later generations are distinctly inferior. The advantages secured by selection are likely to be lost by crossing with a different type. The superiority of selected varieties resides largely in the fact that they show the greatest uniformity in expression of the desired character. When crossing has disturbed this special adjustment of expression relations the superiority of the selected stock is destroyed. Diversity aroused by crossing may serve a useful purpose in furnishing material for a new selection, but this is not the Mendelian idea of forming definite combinations of characters derived from different stocks.

Many of the peculiarities that arise as sudden mutative variations and show Mendelian inheritance are not in the nature of additional characters but represent the absence of normal characters from expression. Hybridization with such variations leads to the subtraction or suppression of characters instead of constituting an addition or positive combination of characters. Mutative variations toward naked, lintless seeds may illustrate this phenomenon in the cotton plant. The lintless character seems to be spreading rapidly in Upland varieties of cotton, especially in the South Atlantic States. The communication of such a negative character by crossing may be much more feasible than the union of two positive characters derived from different stocks, such as the Upland habits of growth and the Sea Island or Egyptian lint.

That mutative suppression of characters is not a rare phenomenon is indicated both in corn and in cotton by the occurrence of albino seedlings. As such albino plants never survive to produce pollen or seeds there can be no question that the loss of the green coloring matter occurs quite frequently as an independent variation.[1]

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[1] Kellicott, W. F. The Social Direction of Human Evolution, 1911, p. 135.

If the superior lint characters of the Sea Island or Egyptian types of cotton could be permanently united with the superior cultural characters of the Upland type of cotton, such as hardiness, earliness, large bolls, and abundant lint, the combination would be valuable. Large numbers of such hybrids have been made, but it has not proved possible to establish their characters by selection. This seems to be prevented by interference of expression relations, as well as by coherence of characters derived from the same parent. Individuals that show definite combinations of the characters of the two types are inferior. Those that show the vegetative characters of the Upland cotton also produce fiber of the short Upland type.[2]

The first generation usually yields better lint than either of the parent varieties, but the later generations are inferior. Perjugate hybrids that have the Upland form not only fail to show long lint like the superior Sea Island or Egyptian ancestor, but usually have very short lint, inferior to that of the original Upland parent of the hybrid stock. The diversities of hybrids, like the mutative variations of selected types, fall into series parallel with the diversities shown in primitive, unselected stocks. In view of the continued transmission of such diversities it is plain that the task of breeding is not to separate the characters in transmission but to understand and control their relations of expression.

An untried possibility of securing more stable combinations of characters derived from different types of cotton has been suggested by a study of diversity. In stocks of Egyptian cotton that have been exposed in previous years to natural crossing some of the lines of descent undoubtedly represent dilute hybrids with Upland or Hindi cotton, in spite of the roguing out of all individuals that showed any definite indication of hybridization in previous generations. Some of the mutative reversions that have appeared in stocks of Egyptian cotton have shown more stable combinations of Uplandlike habits of growth and Egyptianlike lint than any of the hybrids that have been produced artificially.

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[1] A recent paper by Worsley recognizes such limitations in the application of Mendelism to hybrids between different species of plants, as the following paragraphs will show:

"When I have followed these hybrid progeny by critical analysis into the second and subsequent generations, I have not been able to satisfy myself that reversion to certain specific characters follows the allegations of the Mendelian advocates. In the first place, I have never been able to find in hybrids any characters that were absolutely dominant or recessive, but have only discerned a certain relative or partial inclination toward the specific characters. Nor have I as yet found a single instance of absolute reversion to either specific type; but I have found that, in the subsequent generations, all sorts of intermediate forms crop up equipoised between the hybrid type and either parent. For instance, if the hybrid type inclined towards the male in colour of flower and towards the female in another respect, I find that some individuals in subsequent generations will do just the opposite, as though the law of change indicated a course of variation which would in time fill up every gap between the two extreme forms represented by the species originally crossed * * *. We constantly find that certain pairs of characters can not be dissociated from each other, but continually occur together in individuals. This association of certain characteristics (so long as it obtains) appears to rule out the possibility of the occurrence of certain conceptually possible intermediate forms. The Antirrhinums give us one instance of this, for among the dwarf self-colored forms every rogue as to height is also a colour rogue, whereas those that are typical in stature will probably not produce 1 per cent of colour rogues." (See Worsley, A., "Variation as Limited by the Association of Characters." Journal Royal Horticultural Society, vol. 36, pt. 3, May, 1911, pp. 596–597.)

[2] Cook, O. F. Suppressed and Intensified Characters in Cotton Hybrids. Bulletin 147, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 16.

The suggestion is, therefore, that hybridization may serve as a practical means of inducing mutative variations in desired directions in order to secure more stable combinations of characters than are afforded by the more direct methods of hybridization hitherto employed. Mutative reversions often occur as echoes of previous crossing, even after many generations, a fact very familiar to breeders, but such variations do not appear to have been considered as of possible value from the breeding standpoint. That hybridization is responsible for mutations has often been suggested, even in connection with the original examples of the mutation theory—the forms of *Oenothera lamarckiana* described as mutative new species by De Vries. The recent investigations of Davis are pointing more definitely in this direction.[1]

While none of the mutative reversions toward Upland characters in Egyptian stocks have shown such uniform progenies as some of the mutations that have been found in Upland varieties, no complete uniformity could be expected in view of the fact that the parent individuals have produced their seed under conditions of open pollination. That any considerable proportion of the progeny should express the parental characters and be alike among themselves shows a much more stable condition of heredity than has been found to exist in the progenies of any of the individuals that have been selected from second and third generations of hybrid stocks.

This possibility of inducing mutative variations with desirable combinations of characters also seems to be indicated by facts observed in the Durango cotton. Several years ago many hybrids had been made between the Durango cotton and the Triumph variety of American Upland, in order to combine the larger bolls of the Triumph variety with the longer lint of the Durango type, but this work had been discontinued because no uniform progenies of desirable plants were secured. Many large-bolled, Triumphlike plants had also been selected in the Durango stock, but all these were rejected as probably representing accidental hybrids with Triumph, the variety chiefly grown in the vicinity of the earlier experiments. All of these selections behaved like hybrids in their failure to yield uniform progenies.

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[1] Davis, B. M. Genetical Studies on Oenothera. American Naturalist, vol. 45, April, 1911, p. 193.

Nevertheless, occasional large-bolled Triumphlike plants have continued to appear in the Durango cotton and three progenies raised from such plants at Del Rio, Tex., in 1911, were notably uniform, as though the desired combination of characters had finally been secured by mutative variation from the Durango type. If the uniformity of expression continues, superior strains can be developed from these variations. They have the more upright habit and long lint of the Durango type, together with the larger bolls and more abundant lint of the Texas big-boll type. Two of the large-bolled selections showed another big-boll character, an increased proportion of 5-locked bolls. The percentages of 5-locked bolls in these two cases were 42 and 50, while two adjacent rows representing progenies of typical Durango plants showed only 27 and 29 per cent of 5-locked bolls.

The lint percentage was somewhat higher in the large-bolled selections than in the typical Durango type. Yet there seemed to be no constant relation between the lint percentage and the number of locks in the bolls. Another selection with large Triumphlike bolls gave the highest percentage of lint—36 per cent—though in this case only 21 per cent of the bolls were found to have five locks. This indicates a freedom of combination of the Triumph characters in these induced mutations, much as would be expected in Mendelian hybrids. If such mutations prove valuable, they will afford another reason why breeders should not disregard everything except pure lines.

That the percentages of 5-locked bolls represent significant differences among the Durango selections will be seen from the totals shown in Table IV:

Table IV.—*Census of bolls in 5 progeny rows of Durango cotton at Del Rio, Tex.*

Progeny No.	3-locked bolls.	4-locked bolls.	5-locked bolls.	Percentage of 5-locked bolls.	Percentage of lint.
8	0	523	529	50	34
23	5	742	274	27	33
25	1	583	421	42	36
29	0	711	289	29	....
30	2	791	215	21	36

EXPRESSION RELATIONS AFFECTED BY EXTERNAL CONDITIONS.

Expression is influenced by external conditions as well as by internal relations with other characters. That changes of external conditions often result in changes of characters has long been known, and such facts have often been supposed to demonstrate the possibility of improving plants and animals by direct environmental influences. The question whether nature or nurture has the more important influence in development has been widely debated, often to the neglect of the fact that both are essential to full expression of the normal characteristics of a stock. Unless the substratum of transmission is present and accompanied by the necessary potencies of expression the most favorable conditions are powerless to produce a desired character. On the other hand, the most desirable tendencies may prove ineffective in the presence of too unfavorable conditions.

Many differences in degree of development of characters can be looked upon as standing in a direct relation to favorable or unfavorable external conditions. This interpretation of environmental changes does not always suffice. It often becomes evident that some of the changes must be induced indirectly by environmental modifications of internal relations of expression. Cotton plants of the same strain do not merely grow larger in some places than in others, but change their habits of growth, the form of their branches and leaves, the number of carpels in the bolls, and even the color of the fuzz on the seeds.

The Egyptian cotton has different forms of foliage for sun and shade conditions. At Bard, Cal., in October, 1911, it was noticed that leaves of the main stalk and vegetative branches growing in the sun had at least five distinct lobes and those of the fruiting branches at least three lobes. Under shade conditions the leaves of the vegetative branches had three very broad lobes, while those of the fruiting branches were often simple or without lobes. The last was true especially of the lower leaves produced from vegetative shoots in the latter part of the season when there was more shade.

Changes of branching habits in response to different conditions make it evident that there is no complete determination in advance as to whether vegetative or fruiting branches shall be produced. There is a normal sequence in the production of the two kinds of branches, only the vegetative type being produced from the lower nodes of the stalk, but the change from the vegetative to the fruiting type is subject to adaptive accommodation during the development of the plant.

If environmental changes of characters were merely physiological or quantitative the theory of direct adaptation might be sufficient, but such changes are not confined to characters of environmental utility. Many changes of characters induced by environment are disadvantageous, as when cotton plants show excessive development of vegetative branches and fail to ripen seed.

Recognition of the fact that the plants often change their characters without change of external conditions makes it easier to understand how environmental changes may be brought about. Differences that arise in the same stock of plants under different conditions are subject to the same general interpretation as differences that arise under the same conditions, in that both kinds of differences may be supposed to represent changes of expression relations. The characters that are shown in one place belong to the plants as truly as those that are shown in another place. There are environmental alternatives of expression as well as sexual or Mendelian alternatives. The same nodes on the stalk of a cotton plant will produce fruiting branches under some conditions and vegetative branches under other conditions. In this case, indeed, the same character seems to have both Mendelian and environmental relations of expression, for Leake has announced on the basis of experiments with Indian cottons that the habits of branching are inherited in Mendelian fashion. Special attention has been called to this phase of the subject in a recent address of Prof. Bateson.[1]

The varieties that Leake describes as "sympodial" differ from those called "monopodial" merely in producing fruiting branches lower down on the main stalk. As already indicated, these differences are strictly quantitative and physiological, and are readily affected by external conditions, even to the extent that a plant that would be called strictly "sympodial" in one place will become altogether "monopodial" in another, in the sense that all the fruiting branches are transformed into vegetative branches.

Under current theories of Mendelism the failure of one of the contrasted characters to appear is ascribed to a failure of transmission. On this basis it would not be possible for the same varieties of cotton to show the "sympodial" habit in one place and the "monopodial" habit in another. But the facts stated by Leake may be considered as evidence against the application of the Mendelian theory that heredity is a process of alternative transmission. With expression recognized as distinct from transmission there is no reason to deny the possibility that a character expressed in Mendelian fashion among hybrids may also be suppressed or intensified by external conditions. It becomes possible to understand that alternative characters of branches or other organs may remain susceptible to environmental influences as well as to internal relations that govern expression. The influence of external conditions upon heredity has been recognized as one of the most important phases of the subject and one of the most difficult of investigation. An easier approach to such problems is opened by observing the distinction between transmission and expression. The power of the environment to influence the expression of characters can be recognized without assuming that new characters are acquired from external conditions.

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[1] "A simple and interesting example is furnished by the work which Mr. H. M. Leake is carrying out in the case of cotton in India. The cottons of fine quality grown in India are monopodial in habit, and are consequently late in flowering. In the United Provinces a comparatively early flowering form is required, as otherwise there is not time for the fruits to ripen. The early varieties are sympodial in habit, and the primary apex does not become a flower. Hitherto no sympodial form with cotton of high quality has existed, but Mr. Leake has now made the combination needed, and has fixed a variety with high-class cotton and the sympodial habit, which is suitable for cultivation in the United Provinces. Until genetic physiology was developed by Mendelian analysis, it is safe to say that a practical achievement of this kind could not have been made with rapidity or certainty. The research was planned on broad lines. In the course of it much light was obtained on the genetics of cotton, and features of interest were discovered which considerably advance our knowledge of heredity in several important respects. This work forms an admirable illustration of that simultaneous progress both towards the solution of a complex physiological problem and also towards the successful attainment of an economic object which should be the constant aim of agricultural research." (See Bateson, W., "Genetics," Popular Science Monthly, vol. 79, no. 4, October, 1911, p. 319; see also Leake, H. M., "Studies in Indian Cotton," Journal of Genetics, vol. 1, September, 1911, p. 205.)

In addition to the cases where the expression of characters is definitely limited or modified by the external environment there are instances where expression seems to be only slightly modified or modulated to correspond with the more pronounced environmental changes. If external conditions induce the formation of more rounded bolls a shortening of the lint takes place, just as when there has been a definite change of character, as in round-bolled mutations or reversions. Such differences are sometimes quite clearly marked in parts of the same individual plant. Where cotton plants have been checked by drought and afterwards revived, the "top growth" of previously normal plants usually has smaller and more rounded bolls and shorter lint, similar to those of many small-bolled reversions.

Whether such changes are inherited to any extent through the seed has not been demonstrated by any adequate experiments. There is a general belief that the seed of the last picking is not so good for planting as the seed of the first or second picking. In some cases the first picking is also inferior, owing to the fact that many of the very early bolls are poorly developed and are opened prematurely.

The lint also responds in various ways to adverse conditions of growth. In addition to the general weakness of the lint in prematurely opened bolls, the fiber may also be shortened if the adverse conditions affect the boll in the early stages of growth. Another effect of adverse conditions is to render the lint sparse, as well as short. Sometimes these effects are shown unequally on the different parts of the same seed. The upper end of the seed may have lint of normal length and abundance while the lower end has only sparse or short fibers, aggravating the so-called "butterfly" tendency so frequent in our long-staple Upland varieties.

GENERAL CONCLUSIONS REGARDING THE NATURE OF HEREDITY.

Correct interpretations of the facts of heredity are essential to safe application in practical breeding. The investigator should be able to think correctly about the facts that he observes and to appreciate their relations with other facts. Progress in interpretation lends additional value to the results of investigation, like other improvements in methods of conducting experiments and recording observations.

Heredity includes two distinct processes—transmission and expression. If heredity is to be considered from a mechanical standpoint, two kinds of mechanisms should be recognized, a mechanism of expression as well as a mechanism of transmission.

Transmission is independent of expression and probably includes a complete series of ancestral characters. Characters can be transmitted through many generations in a latent condition, without being brought into expression. The study of many problems of heredity and breeding can be facilitated by more definite recognition of the distinction between transmission and expression.

The differences everywhere found among the members of species of plants and animals are the facts that give practical importance to the study of heredity. Such differences should be considered as variations in the expression of characters, not as variations of transmission. Changes of characters that arise in response to changes of external conditions or to different methods of breeding also represent changes in the expression of the characters rather than changes in transmission.

While it would be a matter of much scientific interest to discover the method of transmission, the practical object of the study of heredity is to learn how to control the expression of characters. Expression is influenced by the mutual relations among the characters as well as by external conditions and methods of breeding. The investigation of expression relations should not be limited to empirical discovery of correlations by measurements of sizes, weights, or colors, but should include a biological recognition of expression relations in unimproved stocks and in hybrids.

The idea that variations represent changes in the expression of characters rather than changes in transmission is in accord with the general manifestation of diversity among the members of natural species and the general tendency of domesticated varieties to revert to the ancestral condition of diversity.

Though the recognition of individual diversity and free interbreeding as normal conditions of heredity conflicts with current theories of descent in pure uniform lines, it is necessary to an appreciation of the physiological factors of heredity, those that sustain organic vigor and fertility.

The union of the lines of descent of a normally diverse interbreeding species into a network provides for the transmission of all the ancestral characters through all the lines of descent. Undesirable characters are suppressed by selection, but not eliminated from transmission, as shown by the fact of reversion. The function of selective breeding is to secure more regular expression of a desired set of characters. Continued selection is required to maintain the uniformity of superior varieties, because of the persistent tendency of the suppressed characters to return to expression.

The diversity that is aroused by placing a variety under new or unfavorable conditions and the diversity induced by hybridization can both be looked upon as due to the return of latent characters to expression. It is not necessary to assume that new characters are added to the transmitted stock, either by new conditions or by hybridization.

Selection regulates the expression of characters, but is not known to have any influence over the transmission of characters or the addition of new characters to the content of transmission. The evolutionary development of new characters should not be confused with changes in the expression of old characters. Mutative changes of expression are not to be considered as new characters or as examples of the evolutionary progress of natural species.

The normal results of the workings of heredity seen in natural species are not separate lines of uniform individuals but highly varied fabrics or networks of interbreeding lines of descent. Uniform expression of characters, as in line-bred groups, represents an artificial condition of heredity and is accompanied or followed by a decline of vigor and fertility.

Increased vigor and fertility secured by crossing selected strains is to be considered as a result of returning toward a more normal condition of reproduction, like that of natural, freely interbreeding species. It should not be identified with the abnormal vegetative or somatic vigor sometimes shown by sterile hybrids between different species.

Mendelian combinations of characters of different types of cotton are prevented by the fact of coherence. Instead of a Mendelian segregation and recombination, there is a general tendency for characters derived from the same parental type to remain together in expression in the hybrids.

The transfer of a desired character from one variety to another by Mendelian combination of characters may be possible in cases where the desired character is negative or suppressed, but Mendelian combinations of positive characters are much less frequent, if they occur at all.

The evolutionary development of new organs and functions involves the addition of new characters to the content of transmission, but such new characters are to be distinguished from variations that represent changes in the expression of characters already present in transmission.

SUMMARY OF APPLICATIONS TO METHODS OF BREEDING.

The practical study of heredity should begin with a recognition of the underlying facts of normal individual diversity and free interbreeding among diverse individuals, as shown in wild species and unimproved domesticated stocks. Uniform expression of characters is not a natural condition of heredity in a cross-fertilized plant like cotton, but has to be secured and maintained by selection.

The effect of propagation from a single parent or in very narrow lines of descent is to establish or stabilitate expression, so that a single set of characters is shown in a large number of individual organisms. Normal diversity is suppressed, but the suppressed characters continue to be transmitted in latent form and return to expression in mutative reversions.

In view of the continued transmission of latent or suppressed characters and the frequent return of such characters to expression, it is not to be expected that selection can be completed once for all by the separation of "pure lines," as inferred from the assumption of normally uniform heredity. In a seed-propagated crop plant like cotton continued selection must be maintained if the uniformity of superior varieties is to be preserved. The value of such selection does not depend on the possibility of securing further improvements, but on avoiding degeneration by loss of uniformity.

The idea that there is a natural uniformity or stability of expression of characters applies to natural species only in cases where special methods of reproduction, such as vegetative propagation, parthenogenesis, and self-fertilization, furnish the same conditions of restricted descent as in domesticated species. Vegetative propagation is the most effective method of securing an unaltered expression of the characters of a selected individual, but even in vegetatively propagated varieties changes of expression sometimes occur.

The establishment of uniform expression of characters involves a departure from the normal condition of free intercrossing between different individuals and lines of descent and an ultimate decline in vigor and fertility. Uniform groups become inferior in these respects to hybrids or to select individuals of unimproved stocks.

The loss of vigor and fertility as a result of descent in narrow lines is to be recognized as a general physiological relation or "law of nature." The result appears much more promptly in some groups than in others, but an ultimate deterioration is to be expected in all. While this fact does not diminish the importance of breeding superior strains of domestic animals and plants, it has important bearings on the choice of methods of breeding, testing, and utilizing such strains. Moreover, it shows the need of providing in advance for the continued development of superior new strains to replace those that have begun to decline in vigor and fertility.

The primitive, wild, or unselected stocks from which our highly selected varieties have been derived ought not to be disregarded or allowed to become extinct on the supposition that they have no further agricultural value. Such stocks may be required at any time in the future as sources of new strains.

It is also important for purposes of practical breeding to take into account the facts of heredity in natural species, in order to learn the best methods of maintaining the uniformity of select strains and of preserving vigor and fertility. Some characters have mutual relations of expression and produce more congruous and more stable combinations. Other characters show distinct incompatibility of expression, resulting in weak or infertile plants.

Comparison of variations in select strains with variations in unselected stocks and wild species of cotton shows that parallel series of variations run through the whole group. Correlations of variations in selected stocks and coherence of parental characters in hybrids seem to follow the same general lines in all the species and varieties of cotton that have been studied from this point of view.

Many of the abnormalities that arise in hybrids and in mutative variations of select strains represent a failure of normal specialization among the parts of the plant, as in the shortened fruiting branches and leaflike involucral bracts of the so-called "cluster" cottons. Such abnormalities are usually accompanied by a tendency to sterility or abortion of buds and bolls and on this account are to be avoided in the breeding of new varieties.

Characters of no practical value in themselves may be worthy of careful study as indications of changes of expression of other characters, as in the case of the paler petal spots that are regularly accompanied by small bolls in the Jannovitch variety of Egyptian cotton. The recognition of degenerative mutations and the preservation of uniformity in superior stocks is rendered much more feasible by the fact that the definite changes in the expression of characters are usually simultaneous. A definite variation in one character is usually accompanied by variations in other characters. Plants that would produce inferior lint can be distinguished by vegetative differences before the flowering stage is reached, and their prompt removal prevents the distribution of the pollen of inferior plants by insects.

Both in hybrids and in individual variations of selected stocks of cotton there are relations of expression between boll characters and lint characters, so that the nature of the lint can be judged by inspection of unopened bolls and undesirable variations rejected in advance of the harvesting of the crop.

The two color characters of cotton flowers, the yellow of the petals and the purple of the spots, have very different expression relations. In hybrids between Egyptian and Upland varieties the expression of the lemon-yellow color of the Egyptian petals accompanies other Egyptian characters and is only very rarely combined with distinctive Upland characters. The purple base of the Egyptian petals combines much more readily with Upland characters.

Knowledge of expression relations is also required for effective utilization of hybrids of cotton, corn, and other annual crops for purposes of production. The superior vigor and fertility of conjugate hybrids when compared with select parental varieties grown under the same conditions justifies the use of such hybrids for agricultural purposes of production whenever practicable. The increased vigor and hardiness of hybrids is to be considered as a factor of adaptation when it makes possible the production of good crops under conditions too unfavorable to be resisted by the pure-bred parent varieties.

Variations toward Upland or Hindi characters arising in dilute hybrid stocks of Egyptian cotton have been found to yield progenies with more stable expression of characters than direct hybrids between Egyptian and Upland cotton. Such facts suggest the possibility of developing a new method of breeding by dilute hybridization. By the use of a small proportion of foreign blood as a means of inducing mutative variations in otherwise uniform stocks it may be possible to secure desired combinations of characters in more stable form than they can be obtained by direct hybridization.

The deterioration of the later generations of hybrids may be considered as a return to the expression of the characters of more remote and inferior ancestors; in other words, a loss of the potency of expression of desirable characters that was established by the selection of the parental stocks. Thus, the same general result is reached by hybridization as by neglect of selection. There is a return toward the ancestral condition of variable expression of characters.

PLATES.

DESCRIPTION OF PLATES.

Plate I. Fig. 1.—Kekchi cotton at Bard, Cal., 1911: *A*, Unacclimatized; *B*, acclimatized. The large unacclimatized plant produced only the single boll visible near the base of the main stalk, while the acclimatized plant was heavily loaded with open and unopened bolls. Fig. 2.—Kekchi cotton at Glendale, Cal., 1911. Unacclimatized row at left, acclimatized row at right. In the cooler climate near the coast there were no pronounced differences in the vegetative development of the two rows. The acclimatized stock had somewhat larger bolls and better lint.

Plate II. Normal and abnormal involucres of perjugate (second generation) hybrids between Egyptian and Upland cotton, showing the larger bracts and longer pedicels of sterile involucres: *A*, Hybrid between Mit Afifi Egyptian cotton and Triumph Upland cotton; *B*, hybrid between Mit Afifi Egyptian cotton and Willet Red Leaf Upland cotton.

Plate III. Bolls of Egyptian-Upland hybrid: *A*, From parent plant; *B*, from plant grown from cutting. The bolls produced from the cutting were as large as any that have been produced by seedling plants.

Plate IV. Abnormal involucral bracts of Egyptian cotton, Yuma variety, showing different degrees of specialization and union of the elements that correspond to the blade and stipules of unspecialized leaves. In some cases the stipules are only slightly modified and only slightly attached to the blade. In other cases the specialization is nearly complete, with the parts separated only by a seam or suture instead of being completely fused as in normal bracts.

Plate V. Involucral bracts of Upland "cluster" cotton, "Jackson Limbless": *A*, Normally specialized bracts; *B*, abnormal, intermediate bracts. Deeply divided involucres are often met with in cluster varieties.

Plate VI. Egyptian cotton leaves from three successive internodes, *A*, *B*, and *C*, showing variations of blade and stipules. *A* and *C* represent leaves of the normal 3-lobed form, with small stipules; *B*, the intervening simple leaf with one of the stipules greatly enlarged, representing a partial expression of the characters of the involucral bracts. But after producing an abnormal internode the fruiting branch was able to produce other normal internodes.

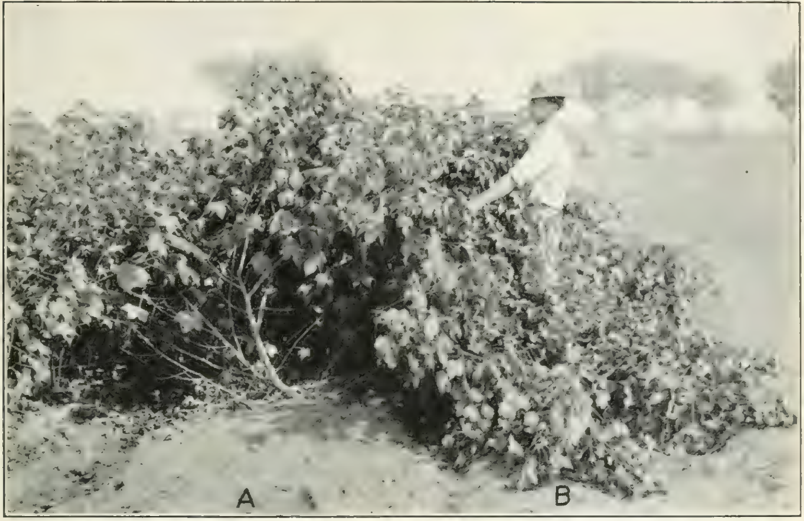


FIG. 1.—PLANTS OF KEKCHI COTTON AT BARD, CAL.: *A*, UNACCLIMATIZED; *B*, ACCLIMATIZED.

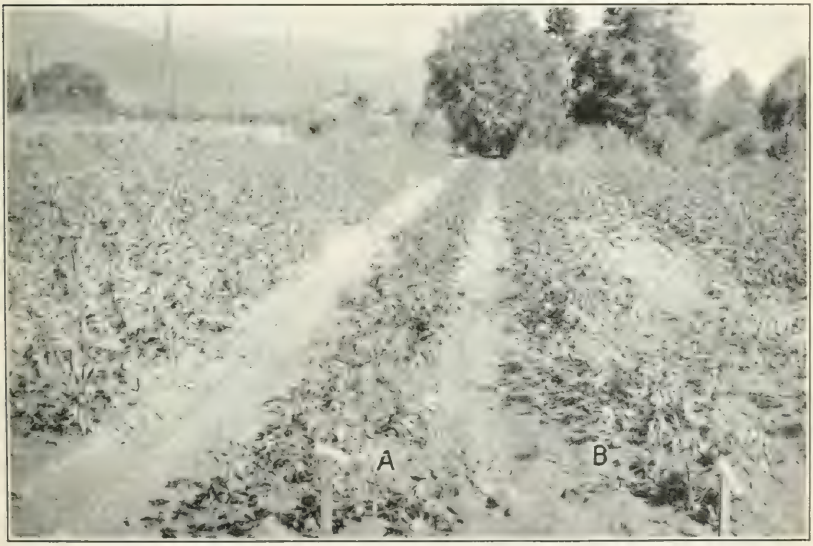
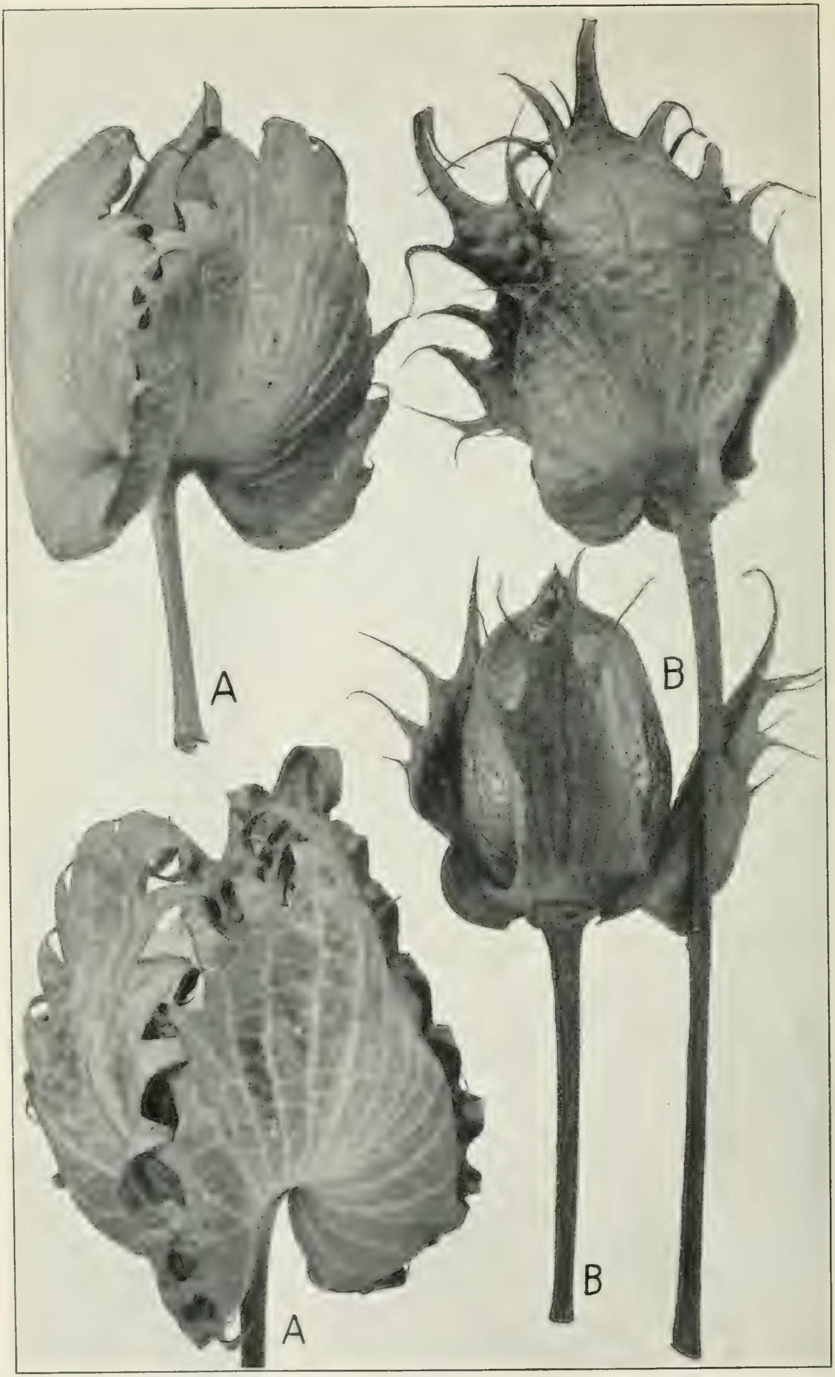
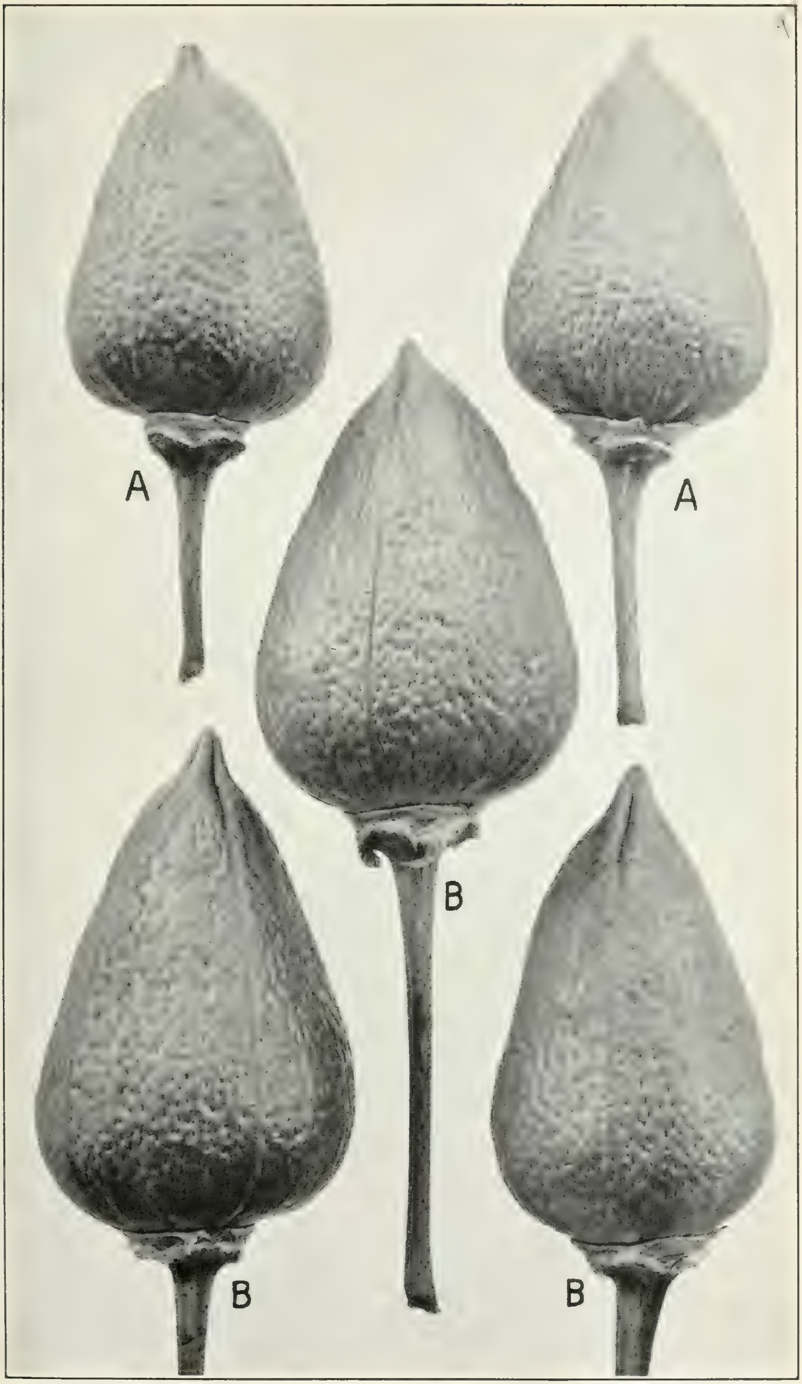


FIG. 2.—TWO ROWS OF KEKCHI COTTON AT GLENDALE, CAL.: *A*, UNACCLIMATIZED; *B*, ACCLIMATIZED.



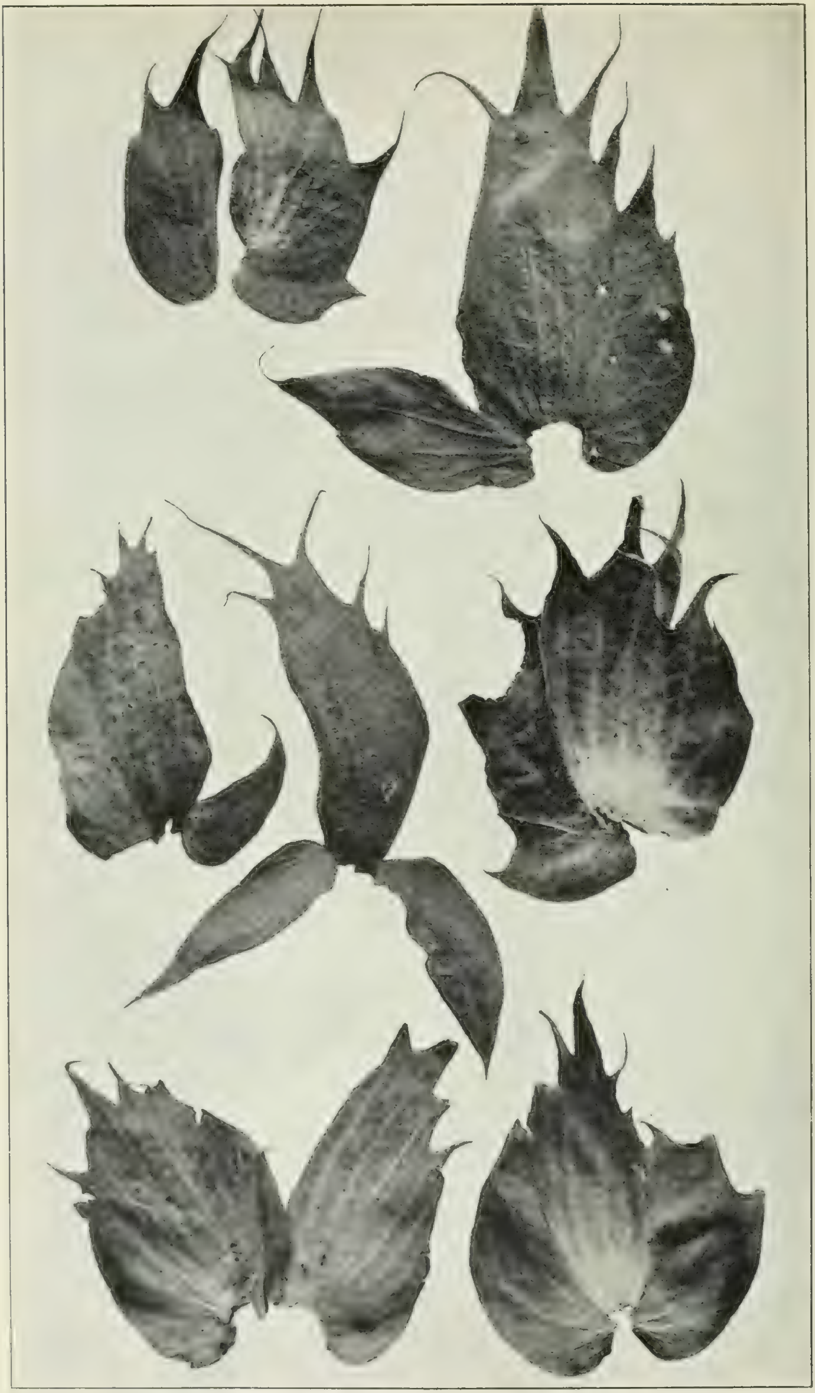
INVOLUCRES FROM TWO PLANTS OF EGYPTIAN-UPLAND HYBRIDS: *A*, NORMAL; *B*, ABNORMAL.

(Natural size.)



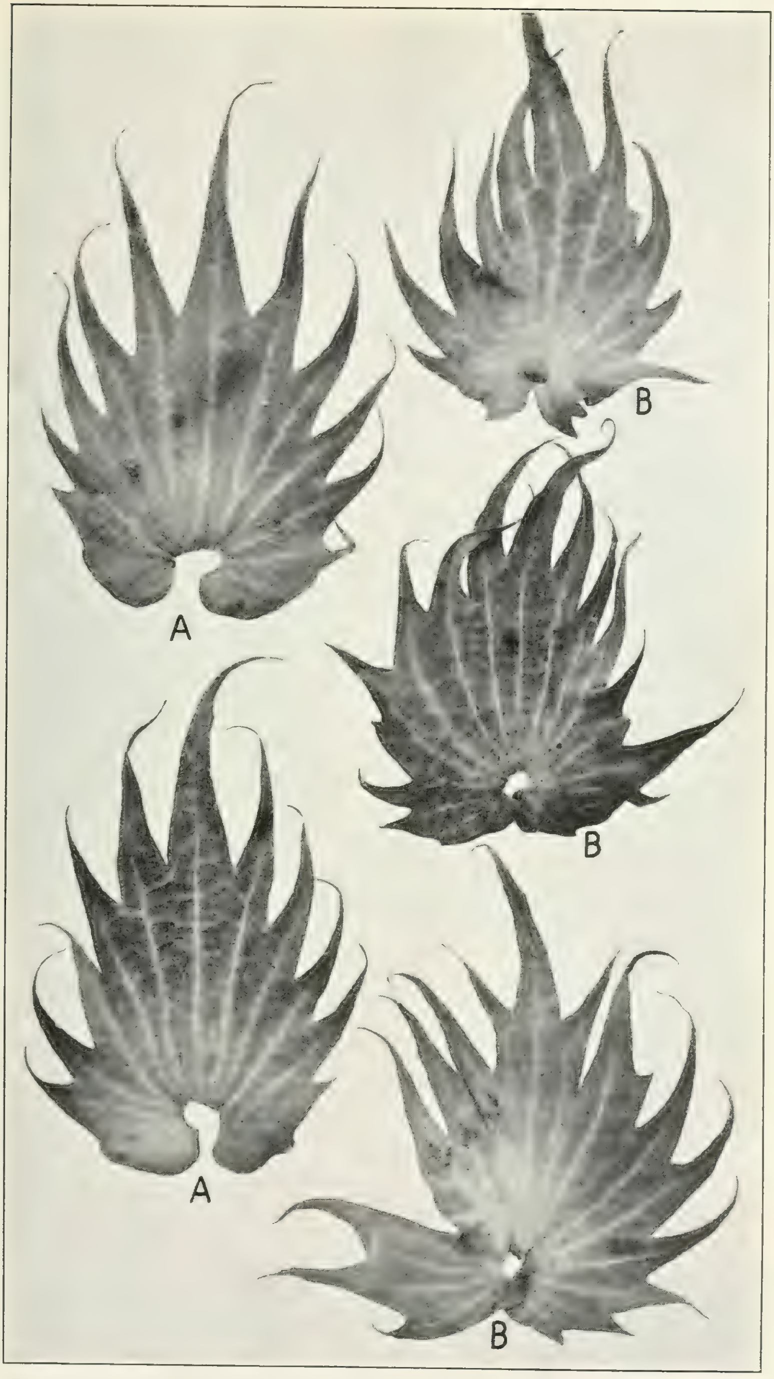
BOLLS OF EGYPTIAN-UPLAND HYBRIDS: *A*, FROM PARENT PLANT; *B*, FROM PLANT GROWN FROM CUTTINGS.

(Natural size.)



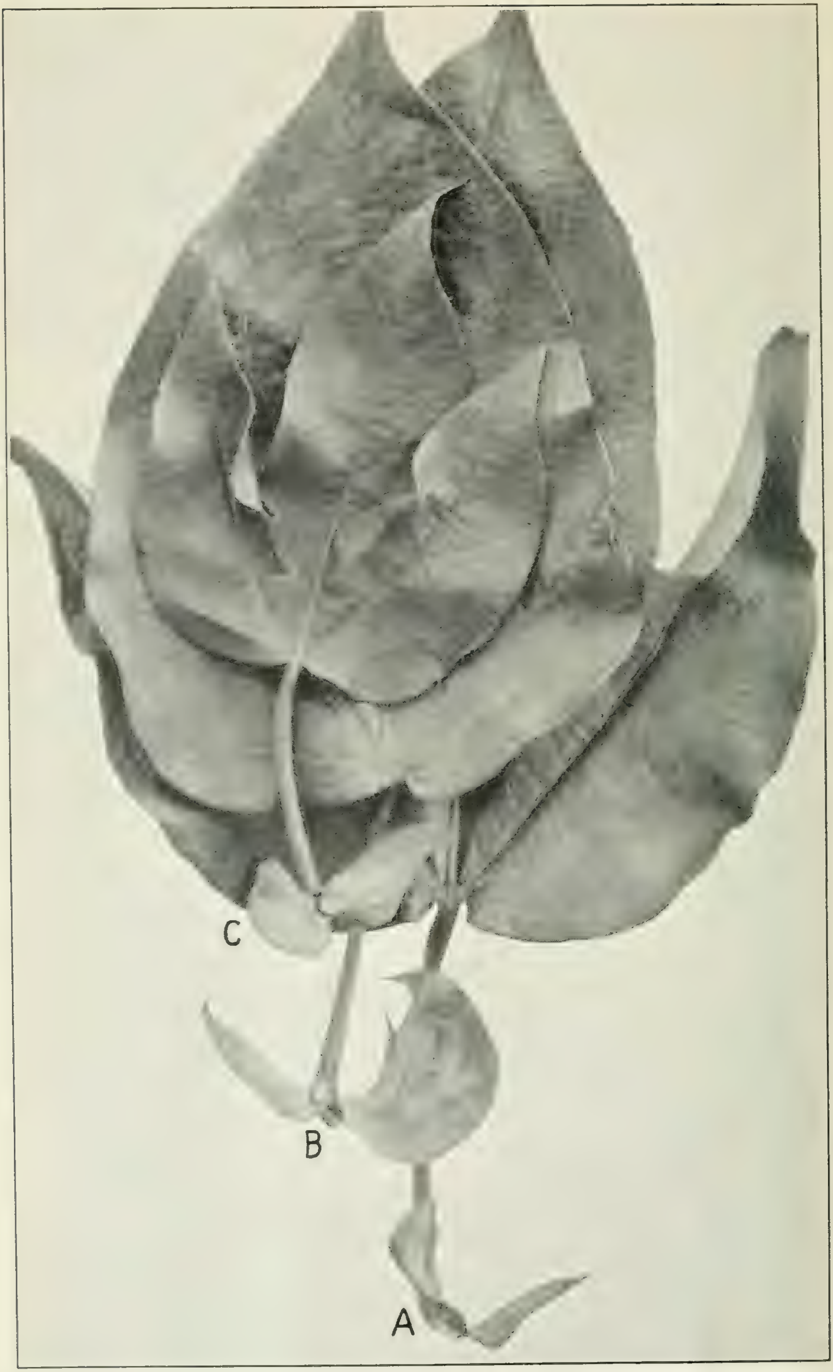
ABNORMAL BRACTS OF EGYPTIAN COTTON, WITH STIPULAR ELEMENTS NOT COMPLETELY UNITED.

(Natural size.)



INVOLUCRAL BRACTS OF "CLUSTER" COTTON, "JACKSON LIMBLESS": *A*, NORMALLY SPECIALIZED BRACTS; *B*, ABNORMAL, INTERMEDIATE BRACTS.

(Natural size.)



EGYPTIAN COTTON LEAVES FROM THREE SUCCESSIVE INTERNODES, *A*, *B*, *C*, SHOWING VARIATIONS OF BLADE AND STIPULES.

(Natural size.)

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BY

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AND

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 18, 1912.

Sir: I have the honor to transmit herewith a manuscript entitled "The Weed Factor in the Cultivation of Corn," prepared by J. S. Cates, Assistant Agriculturist, and H. R. Cox, Agriculturist, in the Office of Farm Management, and to recommend its publication as Bulletin No. 257 of the Bureau of Plant Industry.

This manuscript reports the results of 125 experiments conducted for the purpose of determining the relation of weeds to the tillage requirements of the corn crop. These results show comparative yields of corn on one set of plats under the most approved methods of cultivation and on another set with no cultivation whatever, the weeds being eliminated, however, by surface scraping with a hoe. This work seems to involve a fundamental point and sheds considerable light on the subject of tillage.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—757.

THE WEED FACTOR IN THE CULTIVATION OF CORN.

INTRODUCTION.

Corn is one of the most important crops in the United States. Cultivation is one of the most expensive operations in the production of corn. It is also the operation which, of all phases of corn growing, has probably received the least study or about which we have the least fundamental knowledge.

The soil-mulch theory of tillage has been a fundamental one in American agriculture. It was long ago found that by means of a mulch crops could be grown in alternate years on land receiving such scant rainfall as to make it impossible to grow any satisfactory crop by other methods. In studying the effect of the mulch it has come to be generally recognized that in most soils moisture can be saved by maintaining the top portion of the soil in a finely divided condition. It has also been found that frequent stirring of the soil promotes rapid nitrification. It would seem to follow naturally that a system of cultivation which promotes nitrification and conserves moisture would be an extremely valuable system to apply to a tilled crop. In practice it has been found that in most cases frequent shallow cultivation gives better yields than other methods of corn tillage. Upon this experience tillage philosophy has been developed and tillage practice based.

In this publication data are presented with reference to the weed factor in corn cultivation. A direct comparison has been made between what is considered the ideal method of cultivation for corn in each section in which the experiment was conducted and simply removing the weeds without stirring the soil or producing a mulch. The measure of the relative merits of the two systems has been, not in the preservation of soil moisture, or the effect on nitrification, or the making available of plant nutrients, but the relative yields of corn produced.

Experiments aggregating 125 scattered over 28 States are here recorded. Of this number 12 have previously been recorded in experiment-station literature. A study of the results obtained in these 12 early experiments made it seem desirable to take up in a broad national way the subject of the relation of weeds to the cultivation of corn. Consequently, in the year 1906 a circular letter was sent to the different agricultural experiment stations in the United States giving a general summary of the results already secured and inviting them to cooperate in carrying on simultaneously, through a wide range of soils and climatic conditions, an experiment as outlined to test the relative merits of the mere removal of weeds as compared with supposedly ideal cultivation. A list of graduates of agricultural colleges who are engaged in farming in the various States, together with a number of reliable farmers not coming under that classification, was compiled, and these men were also invited to cooperate with the Department of Agriculture in carrying on the test. The results of these experiments are given in the following pages.

In the tables presented in this bulletin the yields of the uncultivated but weeded plats are expressed in percentages of the cultivated plats, both for fodder and for grain. In the precipitation columns of the tables are given, first, the actual rainfall for a 12-month period, including the last three months of the previous year and the first nine months of the current year, then the mean annual rainfall, and finally the percentage of the actual rainfall expressed in terms of the mean. The records of the weather station nearest to each point where the experiments were conducted or of the station where conditions are most comparable were taken. The columns containing the remarks on soils and climatic conditions give the observations of each of the cooperators covering these points. The headings of the other columns of the tables are self-explanatory.

METHOD OF CONDUCTING THE EXPERIMENTS.

The early tests of five agricultural experiment stations covering the relation of weeds to the tillage requirements of corn were all conducted as a part of a series of experiments on the depth of cultivation. All of them had plats of deep and shallow cultivation, and some had medium-tilled, "standard"-tilled, and mulched plats. The non-tilled plats were referred to as having been "hoed" or "scraped" in all the experiments except those in Utah, where they were "scarified" with a scuffle hoe.

In the work conducted by the Department of Agriculture, beginning in 1906, an outline was furnished each cooperator describing in detail how the test should be made. The salient points in the outline were as follows: A piece of land of very even productivity was to be selected; preparation for planting was to be made by thorough breaking and harrowing and the planting was to be done by drilling on level land—that is, without ridges.

The size of the plats was left to the cooperator. In the work from 1906 to 1910 the plats consisted for the most part of five rows each, making with the one intermediate row which was discarded at harvest, 11 rows in the experiment. In the work of 1911 most of the experiments were conducted on four plats of five rows each, with three intermediate rows, one between every two plats, which were discarded at harvest. The length of the plats varied with the convenience of each man, the average length being about 250 feet.

After planting, one plat or series of plats was to receive absolutely no cultivation, the weeds and grass being removed at frequent intervals by means of a sharp hoe. This hoe was to be used with a horizontal stroke to cut off the vegetation at the soil surface, and particular care was to be paid not to stir the soil any more than was absolutely necessary. The other plat or series of plats was to receive the ordinary cultivation and in addition to have the weeds and grass removed by chopping so as to eliminate the weed factor. Figure 1 shows the typical appearance of the soil on a cultivated plat and figure 2 on an uncultivated plat when the plants had reached the tasseling stage. These illustrations show the tests at the Arlington Experimental Farm on a stiff clay soil where the surface of the uncultivated plats was nearly as dry and hard as a floor.

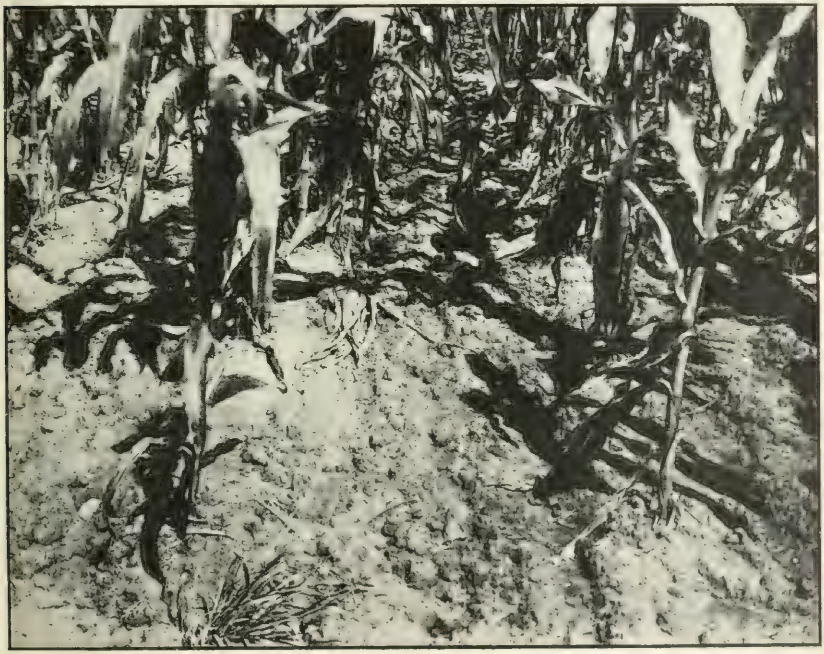

FIG. 1.—Typical appearance of the soil on a cultivated plat of corn.

The cooperators entered into the work with enthusiasm, and as a rule the tests were well conducted. Many experimenters were visited each year by a representative of the Bureau of Plant Industry, who advised with them on the subject. At the completion of the tests detailed statements of the various phases of the experiment were reported on special blanks furnished by the Department. Some of the reports were incomplete or indicated that the work had not been properly carried out. All such were discarded in the final compilations.

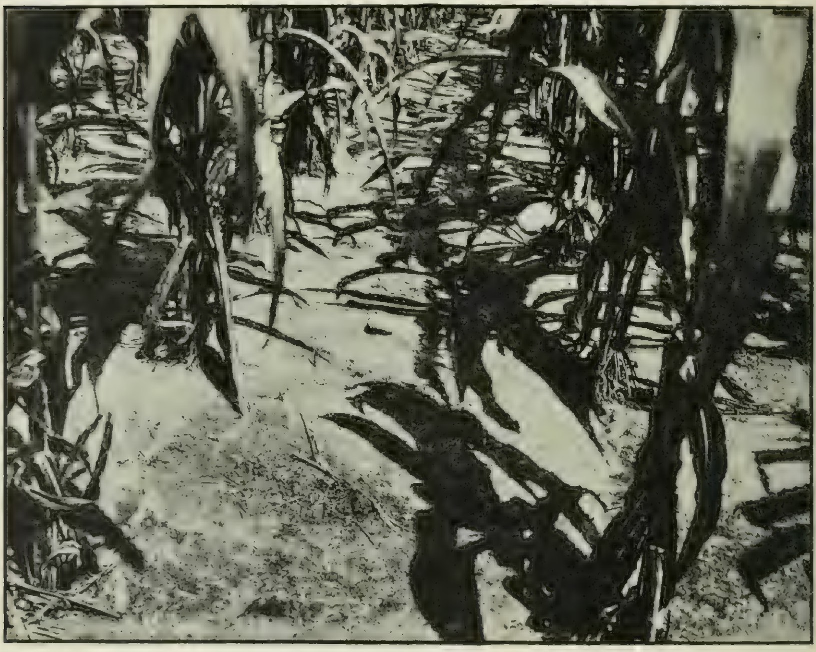

FIG. 2.—Typical appearance of the soil on an uncultivated plat of corn.

EARLY EXPERIMENTS IN CORN CULTIVATION.

Probably the first agricultural experiment station, at least in this country, to take note of the weed factor in cultivation was the New York State station, at Geneva. The results are presented in the annual report of that station for 1886. Sturtevant in discussing these results says:

> If this experiment has a meaning, it is that cultivation is not beneficial to the corn plant except so far as removing the weeds is concerned. Strangely enough, we have during the existence of the station been unable to obtain decisive evidence in favoı of cultivation.

The next station to take up this study was Illinois. Under the direction of Morrow and Hunt the work was begun in 1888 and continued until 1893; it was taken up again in 1896, thus covering seven years.

In 1889 and 1890 the Missouri Agricultural Experiment Station made investigations on the depth of cultivation and included plats that were weeded but not cultivated. These experiments included the effect of the treatments on soil moisture for the year 1890. This work was started by Sanborn, who, upon his retirement to become director at the Utah station, started the same kind of work at the latter place.

In 1898 and 1899 the South Carolina station made tests of various methods of planting and depths of cultivation, and included a plat that was weeded but not cultivated.

The results of all these experiments, with the exception of those in Utah, are shown in Table I.

TABLE I.—*Results of early experiments in corn tillage.*

Location of State experiment station.	Year.	Yield per acre.				Yield of uncultivated plat expressed as percentage of cultivated.		Precipitation.		
		Cultivated plats.		Uncultivated plats.				For last 3 months of preceding and first 9 months of current year.	Mean.	Comparison with mean.
		Fodder.	Grain.	Fodder.	Grain.	Fodder.	Grain.			
		Lbs.	*Bush.*	*Lbs.*	*Bush.*			*Inches.*	*Inches.*	*Per ct.*
Geneva, N. Y.[1]	1886	....	56.8	....	70.5	....	124.1	32.66	32.81	99.5
Urbana, Ill.[2]	1888	....	93.8	....	90.0	....	95.9	40.11	35.74	112.2
	1889	....	84.6	....	77.1	....	91.1	41.74		116.7
	1890	....	66.8	....	69.1	....	103.4	39.16		109.5
	1891	....	58.4	....	55.3	....	94.7	25.09		70.2
	1892	....	70.1	....	76.8	....	109.5	42.70		119.4
	1893	....	36.3	....	28.7	....	79.0	37.72		105.5
	1896	....	85.5	....	87.0	....	101.7	40.00		111.9
Columbia, Mo.[3]	1889	3,920	80.1	3,900	82.0	99.5	101.3	42.34	38.46	110.0
	1890	2,205	54.0	1,570	45.7	71.2	84.6	40.86		106.2
Clemson College, S. C.[4]	1898	....	58.6	....	56.5	....	96.4	48.35	51.14	94.6
	1899	....	67.3	....	67.5	....	100.3	50.11		98.0
Total	......	6,125	812.3	5,470	806.2	....	....	480.84	....	....
Average	......	3,062	67.69	2,735	67.18	85.35	98.5	40.07	38.51	104.4

[1] Annual Report, 1886, p. 46.
[2] Illinois Bulletins 20, 25, 31, 46.
[3] Missouri Bulletin 14.
[4] South Carolina Bulletin 61.

EXPERIMENTS IN UTAH.

Table II shows the results of seven years' work covering experiments on corn cultivation made at the Utah Agricultural Experiment Station, as recorded in Bulletin No. 66 of that station. As these experiments were made under irrigation conditions, the data are not included in the discussions of the other early experiments or in the résumé on page 24. It is apparent that the "no tillage" treatment did not receive a fair trial, since, to quote the bulletin mentioned, page 129, "the weed pulling by hand loosened the soil to a considerable extent, for they were not pulled until large enough to be easily taken hold of, and they were always plentiful." In a recent letter Prof. Sanborn describes the treatment of the "scarified" plats, showing that it was practically identical with the nontilled treatment of our work. In this connection, therefore, the scarified plats should be compared with either the shallow-tilled or medium-tilled plats.

It will be noted in Table II that the average figures of all the years for the scarified plats is 58.87 bushels of grain and 3,036 pounds of fodder, as compared with 52.91 bushels of grain and 3,487 pounds of fodder for the shallow-tilled plats and 57.31 bushels of grain and 3,431 pounds of fodder for the medium-tilled plats.

TABLE II.—*Results of experiments in corn tillage in Utah.*

Year.	Yield per acre.											
	Shallow tillage.		Medium tillage.		Deep tillage.		No tillage.		Mulched with dirt.		Scuffle hoe (scarified).	
	Fodder.	Grain.	Fodder.	Grain.	Fodder.	Grain.	Fodder.	Grain.	Fodder.	Grain.	Fodder.	Grain.
	Pounds.	*Bush.*	*Pounds.*	*Bush.*	*Pounds.*	*Bush.*	*Pounds.*	*Bush.*	*Pounds.*	*Bush.*	*Pounds.*	*Bush.*
1890 to 1892[1]	1,704	16.75	1,981	15.80	1,169	27.08	1,574	12.35	1,270	16.69	2,286	23.10
1893	1,666	37.52	2,433	54.18	2,866	61.11	2,933	67.23	2,844	76.18	2,000	43.60
1894	2,800	51.81	3,467	69.22	3,067	52.76	3,600	52.38	3,067	56.38	2,800	57.33
1895	....	57.14	....	54.09	....	50.67	....	63.43	....	60.75	....	72.19
1896	8,067	79.04	6,606	75.14	9,600	66.66	6,227	71.05	8,160	76.57	4,360	69.33
1897	3,200	75.22	2,667	75.41	1,867	79.41	2,667	44.75	3,467	48.75	3,733	77.69
Average	3,487	52.91	3,431	57.31	3,714	57.45	3,400	51.86	3,762	55.89	3,036	58.87

[1] Average for the two years.

EXPERIMENTS OF THE BUREAU OF PLANT INDUSTRY.

In 1905 the senior writer collected the early data of the State agricultural experiment stations and conducted a test on corn cultivation at Ithaca, N. Y. On becoming a member of the staff of the Department of Agriculture he carried on similar tests in 1906 in cooperation with three experiment stations and in 1907 with four stations, one individual, and the Arlington Experimental Farm of the Department. In 1908 the work was conducted by four stations, one individual, and the test farm at Arlington. In 1909, 1910, and 1911 it was carried on in cooperation with various farmers in different parts of the United States.

Figure 3 shows the shocked corn from the plats at the Arlington Experimental Farm in 1908. One of the shocks is from a cultivated plat, the next one from an uncultivated plat, and thus alternating through the series. Figure 4 shows the ear corn from the same experiment, one pile being from a cultivated plat, the next one from an uncultivated plat, and thus alternating. Figure 5 illustrates the experiment of Mr. J. J. Lee, Cynthiana, Ky., in 1909, showing the uncultivated plat and the cultivated plat. Figure 6 shows the fodder and ear corn from the experiment of Mr. Geoffrey Morgan, Whites Station, Ky., in 1910, both cultivated and uncultivated.

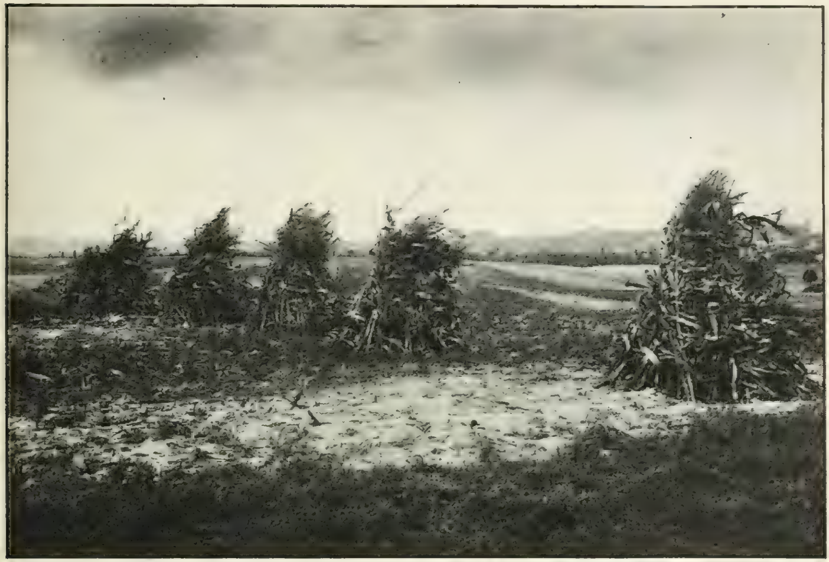

FIG. 3.—Shocks from the corn experiment at the Arlington Experimental Farm, 1908. The shock at the right is from a cultivated plat, the next one from an uncultivated plat, and so on.

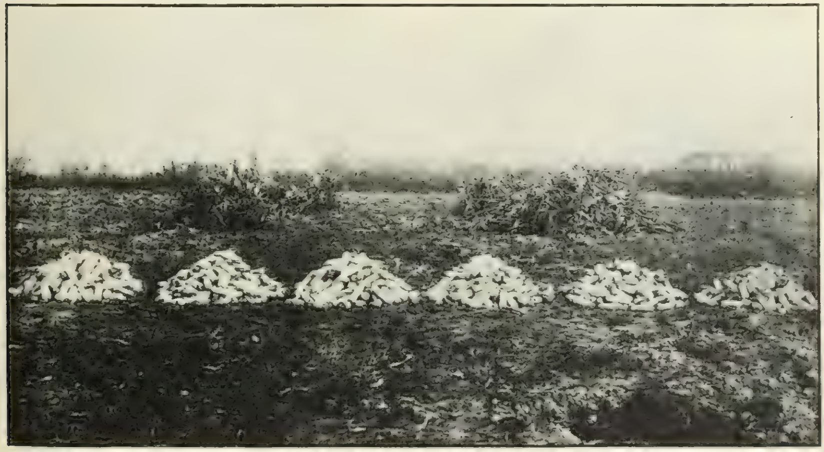

FIG. 4.—Ears of corn from the same shocks shown in figure 3. The corn at the left was cultivated, that in the next pile uncultivated, and so on.

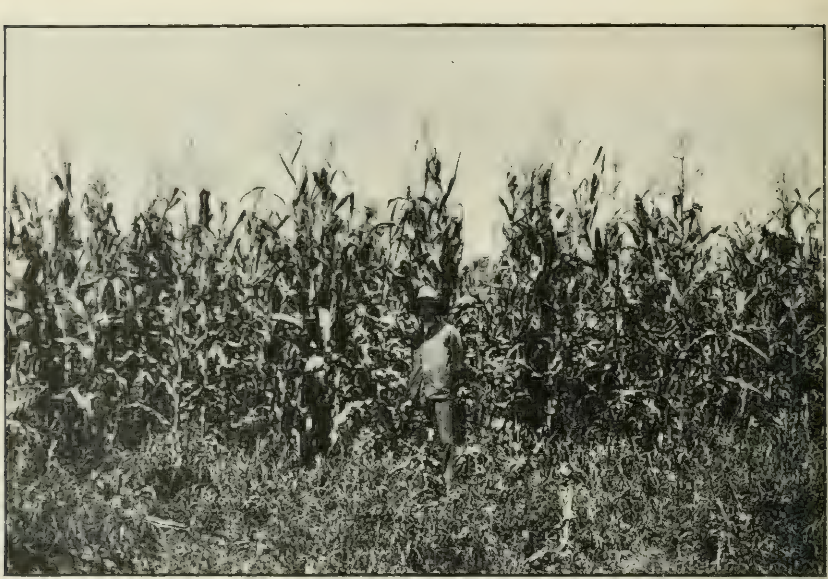

FIG. 5.—Cultivated and uncultivated plats of corn, the experiment of Mr. J. J. Lee, Cynthiana, Ky., in 1909. The uncultivated plat is shown in the left half of the illustration and the cultivated plat on the right.

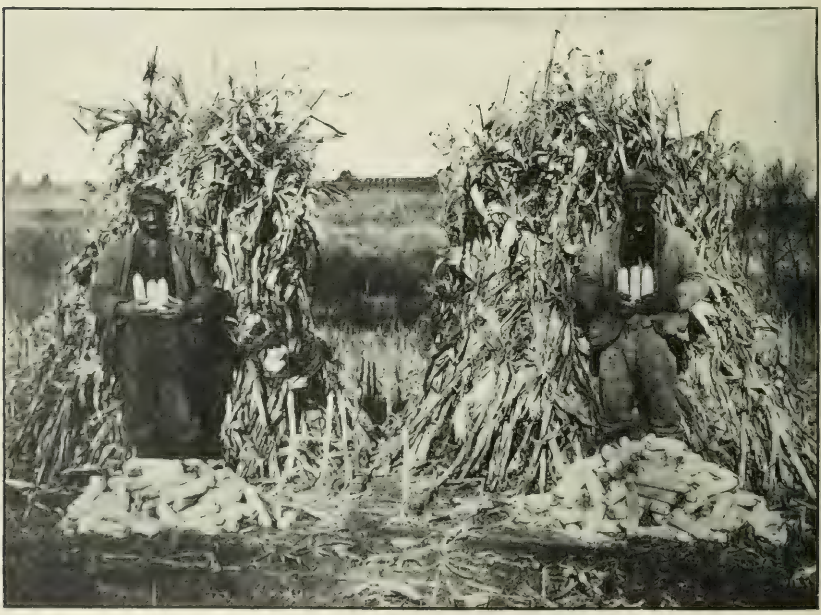

FIG. 6.—Cultivated and uncultivated fodder and ears of corn, the experiment of Mr. Geoffrey Morgan, Whites Station, Ky., in 1910. The cultivated fodder and corn are at the left of the illustration and the uncultivated at the right.

Figure 7 represents one of the three pairs of uncultivated and cultivated plats at Arlington in 1911, photographed just before tasseling.

A number of experiments were carefully conducted up to a certain point and were then discontinued for various reasons, such as stock breaking in, storms blowing down the corn, or the plats being harvested together by mistake. Of 15 such discontinued experiments 8 showed practically no difference between the cultivated and uncultivated plats at the time of the discontinuance; 4 were in favor of the uncultivated and 3 in favor of the cultivated treatment.

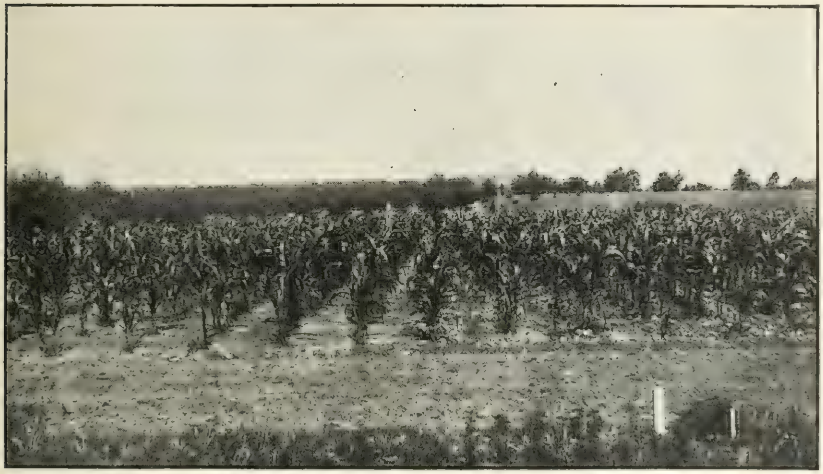

FIG. 7.—One of three pairs of corn plats at the Arlington Experimental Farm in 1911. The uncultivated corn is at the left and the cultivated at the right.

Table III gives the data for the seven years 1905 to 1911.

TABLE III.—*Results of experiments in corn tillage for the years 1905 to 1911, inclusive.*

Name and address of experimenter.	Year.	Yield per plat.				Yield of uncultivated plat expressed as percentage of cultivated.		Size of plat.	Yield per acre (calculated).				Precipitation.			Remarks.
		Cultivated.		Uncultivated.					Cultivated plats.		Uncultivated plats.		Last 3 months of preceding and first 9 months of current year.	Mean.	Comparison with mean.	
		Fodder.	Grain.	Fodder.	Grain.	Fodder.	Grain.		Fodder.	Grain.	Fodder.	Grain.				
Cates, J. S., Ithaca, N. Y.:		*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*			*Acres.*	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Ins.*	*Ins.*	*P. ct.*	
Plat 1	1905	33	35	29	32	87.8	91.4	......	......	......	......	......	35.05	32.97	94	Rolling land.
Plat 2	1905	29	28	26	28	89.6	100	......	......	......	......	......	......	......	......	Level land.
Michigan experiment station, East Lansing, Mich.	1906	......	473	......	535	......	113.1	......	......	......	......	......	28.94	30.99	107	
New Hampshire experiment station, Durham, N. H.	1906	1,960	1,631	2,190	2,310	111.7	141.6	......	1,960	23.3	2,190	33	39.73	40.67	102.3	
Purdue experiment station, Lafayette, Ind.	1906	......	370	......	355	......	95.9	0.1125	......	46.97	......	45.04	38.17	36.83	96.5	
Total	......	2,022	2,537	2,245	3,260	......	......	.1125	1,960	70.27	2,190	78.04	......	......	......	
Average	......	674	507.4	748.3	652	96.36	108.4	.1125	......	35.13	......	39.02	35.47	35.36	99.95	
Arlington Experimental Farm, Rosslyn, Va.:																
Plat 1	1907	......	104.04	......	123.76	......	118.9	......	......	......	......	......	44.73	40.80	109.6	Clay soil; planted 3.3 by 3.3 feet.
Plat 2	1907	......	157.41	......	134.64	......	85.5	......	......	......	......	......				Gently sloping; planted in rows 3.3 feet apart, half that distance between hills.
Cornell experiment station, Ithaca, N. Y.	1907	......	3,522	......	3,643	......	103.4	......	......	50.3	......	52.0	33.25	32.97	100.7	Rather sandy; rolling.
Froley, J. W., Springfield, Md.	1907	......	151	......	165	......	109.2	.033	......	65.3	......	71.3	40.13	41.80	96	
Michigan experiment station, East Lansing, Mich.:																
Plat 1	1907	270	287	243	471	89.6	164.1	......	......	......	......	......	33.18	30.99	107	Sandy, gravelly loam; Rustler.
Plat 2	1907	251.7	225	235.6	225	93.6	100	......	......	......	......	......				Level; Silver King. Spring cold and wet.

Nebraska experiment station, Lincoln, Nebr.	1907	....	4,333	....	4,417	....	101.9	....	....	61.9	....	63.1	28.41	27.51	103.2	Alfalfa sod; good soil.
Purdue experiment station, Lafayette, Ind.	1907	....	1,077.5	....	1,118	....	103.7	.2	....	77	....	79.8	38.44	36.83	104.3	Extremely wet.
Total	......	521.7	9,856.95	478.6	10,297.4	....	....	.233	....	254.5	....	266.2	....	....	....	
Average	......	260.8	1,232.12	239.3	1,287.17	91.6	110.84	.1165	....	63.6	....	66.55	36.36	35.15	103.47	
Arlington Experimental Farm, Rosslyn, Va.	1908	197.5	290	186	283.5	94.2	97.7	.10	1,975	41.4	1,860	40.5	42.86	40.80	105	Clay; slightly sloping.
Campbell, J. M., Richardson, Tex.	1908	285	264	251	268	88	101.5	....	....	....	....	....	46.39	42.62	108.7	Black waxy soil; level.
Minnesota experiment station, St. Paul, Minn.	1908	270	450	270	450	100	100	.10	2,700	62.5	2,700	62.5	29.99	27.80	107.7	Sandy loam; average season.
New Hampshire experiment station, Durham, N. H.	1908	4,980	4,953	4,860	4,974	97.6	100.4	....	4,980	67.9	4,860	68.2	43.09	40.67	105.8	
North Carolina experiment station, W. Raleigh, N. C.	1908	....	808.5	....	744.1	....	92	....	....	11.55	....	10.63	61.05	49.47	123.2	Raw, poor, black-jack clay.
Purdue experiment station, Lafayette, Ind.	1908	....	4,375	....	4,200	....	96	....	....	62.5	....	60	33.00	36.83	89.8	
Total	......	5,732.5	11,140.5	5,567	10,919.6	....	....	.20	9,655	245.85	9,420	241.83	....	....	....	
Average	......	1,433.1	1,856.8	1,391.7	1,819.9	94.95	97.93	.10	3,218	49.17	3,140	48.36	42.74	39.69	106.7	
Anderson, W. B., Velpen, Ind.	1909	(1)	337	(1)	460	....	136.5	.10	....	48.1	....	65.65	35.80	40.77	87.9	Yellow clay, rolling; wet early part of season.
Arlington Experimental Farm, Rosslyn, Va.	1909	445	321	408	238	91.7	74.1	.15	2,966	30.6	2,720	22.7	34.42	40.80	84.4	Stiff clay, packed hard; sloping; period of drought during summer.
Barrett, J. M., Napton, Mo.	1909	(1)	190	(1)	235	....	123.7	.052	....	52.2	....	64.57	39.78	36.50	108.9	Silt loam, level; fairly good season, except 5 weeks dry weather after July 27.
Callison, N. A., Gainesville, Fla.	1909	710	580	680	505	95.8	87.1	.327	2,171	25.3	2,077	22.02	39.73	51.34	77.4	Sandy loam, level; rather dry season.
Campbell, J. M., Richardson, Tex.	1909	....	214	....	143	....	66.8	.250	....	12.2	....	8.15	16.18	39.04	41.4	Black waxy, level; very dry season.
Cunningham, T. J., Chester, S. C.	1909	[2] 27	173	27	199	100	115	.096	....	22.5	....	25.9	47.99	49.13	97.6	Gravel, clay subsoil; rolling land; wet season.
Day, A. P., West Kennebunk, Me.	1909	[1] 665	....	[1] 575	....	86.5	....	.154	....	....	....	....	37.36	42.63	87.6	Sandy loam, clay subsoil, sloping slightly; extremely dry season.
Dimond, O. C., West Concord, N. H.	1909	153	166	[3] 186	201	121.5	121.1	.038	4,050	62.4	4,891	75.6	30.14	39.82	75.7	Strong loam; hill land, with gentle slope; rather dry season.
Foster, W. L., Shreveport, La.	1909	(1)	375	(1)	430	....	114.7	.322	....	16.6	....	19.04	29.64	45.45	65.2	Sandy loam, level; wet in early part of season.
Lambert, F. L., Charles City, Iowa.	1909	....	261	(4)	301	....	115.3	.066	....	56.4	....	65	36.57	31.29	116.8	Sandy loam, level; good season.
Lee, J. J., Cynthiana, Ky.	1909	[4] 555	494	547	474	98.5	96	.0868	6,393	81.3	6,298	78	47.08	43.99	107.2	Dark loam, level; wet season.

[1] No difference in time of ripening.

[2] Ripened slightly earlier.

[3] Ripened a few days earlier.

[4] Ripened earlier.

TABLE III.—*Results of experiments in corn tillage for the years 1905 to 1911, inclusive*—Continued.

Name and address of experimenter.	Year.	Yield per plat.				Yield of uncultivated plat expressed as percentage of cultivated.		Size of plat.	Yield per acre (calculated).				Precipitation.			Remarks.
		Cultivated.		Uncultivated.					Cultivated plats.		Uncultivated plats.		Last 3 months of preceding and first 9 months of current year.	Mean.	Comparison with mean.	
		Fodder.	Grain.	Fodder.	Grain.	Fodder.	Grain.		Fodder.	Grain.	Fodder.	Grain.				
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*			*Acres.*	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Ins.*	*Ins.*	*P. ct.*	
Leffler, G. V., Stockport, Iowa.	1909	....	156	....	171	......	109.6	0.055	......	40.5	....	44.4	32.44	34.97	92.8	Heavy loam, level; rather dry season.
Littlejohn, W. D., Kentland, Ind.	1909	....	171	(1)	163	......	95.3	.0331	......	73.8	....	70.4	48.08	36.13	133	Black sandy loam, level; wet season.
McCune, Kate B., Shedd, Oreg.	1909	(2)	47	(2)	50	......	106.5	.0062	......	107.4	....	114.2	....	......	......	Clay loam, level; rather dry season.
Merwin, G. H., Southport, Conn.	1909	(2)	540	(2)	540	......	100	.0984	......	78.4	....	78.4	42.20	45.89	92	Heavy loam, level; fairly good season.
Perry, J. B., Clarks Falls, Conn.	1909	[1] 331	264.5	320.5	287.7	96.5	108.7	.0827	4,002	45.7	3,872	49.6	45.84	46.18	99.4	Light loam, hardpan, gravelly subsoil, level; dry season.
Purdue experiment station, Lafayette, Ind.	1909	....	2,940	....	2,947	......	100.25	......	......	42	....	42.1	46.80	36.83	127	
Rich, E. A. J., Brinson, Ga.	1909	342	309	373	429	109	138.8	.1446	2,365	26.7	2,579	37.04	36.10	49.90	72.3	Sandy loam, level; rather dry season.
Sawyer, R. S., Walpole, N. H.	1909	....	785	....	542	......	69.1	.1572	......	71.3	....	49.2	36.77	41.04	89.5	Do.
Seay, Robt., Emporia, Va.	1909	[2] 160	201	[2] 169	162	105.6	80.6	.0965	1,658	29.7	1,751	23.95	50.47	45.89	110	Sandy loam, level; dry.
Sugar experiment station, New Orleans, La.	1909	(2)	99.3	(2)	99.3	......	100	.0602	......	20.6	....	20.6	59.23	55.63	106.4	Heavy sandy loam, level; average season.
Tenney, W. P., Chester, N. H.	1909	(2)	425	(2)	725	......	170.5	.1944	......	31.25	....	53.2	30.14	39.82	75.7	Medium to light loam, level; very dry season.
Wallace, M., Marion, S. C.	1909	(2)	2,947	(2)	2,709	......	91.9	.496	......	84.9	....	78	40.24	46.55	86.5	Clay, level; season a little dry.
Watson, D. A., Durham, N. H.	1909	....	238	....	236	......	99.1	.0505	......	67.4	....	66.8	33.79	42.17	80.2	Fine clay loam, sloping; season dry and cold.
Welch, E. K., Northwood Center, N. H.	1909	[2] 302	170	[2] 320.5	186.5	106.1	109.7	.0378	......	64.2	....	70.4	30.14	39.82	75.7	Sandy loam, gravelly with hardpan subsoil; hilly; season unfavorable.

Wollschlaeger, Gus, Boerne, Tex.	1909	(2)	340	(2)	346	....	101.7	.253	....	19.2	....	19.55	22.26	31.42	70.9	Black waxy, hilly; very dry season.
Total	.....	3,690	12,743.8	3,606	12,779.5	....	....	3.4074	23,605	1,210.65	24,188	1,264.83	....	....	....	
Average	......	369	509.7	360.6	511.2	101.15	105.27	.1363	3,372	48.42	3,455	50.59	37.96	42.13	90.46	
Anderson, W. B., Velpen, Ind.	1910	....	804	....	798	....	99.2	.1285	....	62.6	....	62.2	40.47	40.77	99.4	Light clay, level; season very wet.
Bigstaff, T. J., Mount Sterling, Ky.	1910	6,890	2,680	[1] 6,300	2,590	91.4	96.6	1.016	4,145	37.65	3,650	36.39	61.85	48.10	128.6	Clay loam, gently rolling; season very wet.
Brant, W. C., Ruffin, S. C.	1910	[2] 130.75	141.25	[2] 184	135	140.6	95.5	.0287	4,550	70.3	6,408	67.2	47.84	50.02	95.7	Light sandy, level; heavy rains.
Campbell, J. M., Richardson, Tex.	1910	....	115.7	....	124	....	107.1	.0689	....	24	....	25.71	27.74	39.04	71.1	Black waxy, level; very dry; less than 4 inches of rain after planting.
Case, J. H., Lawrenceburg, Ky	1910	....	4,550	(1)	4,900	....	107.7		....	65	....	70	46.03	43.58	105.7	Uniform clay loam, hilly.
Crum, H. C., Denmark, S. C.	1910	(1)	168.7	....	192.8	....	114.3	1.1147	....	21	....	24	41.09	47.89	85.8	Sandy loam, red clay subsoil; too much rain.
Dailey, S. C., North Baltimore, Ohio.	1910	904	1,347	[3] 872	1,202	96.4	89.2	.2315	3,900	83.1	3,765	74.1	35.18	38.35	91.7	Loose black soil, level; fair season, but dry in August.
Day, A. P., West Kennebunk, Me.	1910	164	146	153	127	93.3	87	.0413	3,970	47.9	3,705	41.7	32.10	42.63	75.3	Clay loam, gently sloping; favorable season.
Dimond, O. C., West Concord, N. H.	1910	[1] 300	274	254	249	84.6	90.9	.0432	6,950	90.6	5,875	82.4	29.59	39.82	74.3	Strong loam, rolling; wet early; dry late.
Elmer, E. O., Devereaux, Mich.	1910	[2] 68.9	118	[2] 67.9	120.2	98.6	101.8	.0197	3,497	85.6	3,448	87.1	30.83	33.33	92.6	Clay loam, level; wet and cold after planting; very dry during July.
Ferguson, A. M., Sherman, Tex.	1910	....	86	....	82.5	....	95.9	.2169	....	5.67	....	5.43	22.09	38.25	57.7	Black waxy, some sand; very dry during growing period.
Finley, W. W., North Wilkesboro, N. C.	1910	....	392	(1)	362	....	92.3	.1147	....	48.8	....	45.1	46.23	57.63	80.2	Red clay, level; rainy in June, dry in July.
Fredericks, C. P., Sunbury, Ohio.	1910	189	161.2	[4] 168.8	171.4	89.3	106.4	.0459	4,120	50.14	3,680	53.34	33.48	36.68	91.3	Clay loam, level; fair season.
Gardner, E. T., Fowler, Colo.	1910	[2] 144.4	71.8	[2] 128.2	64.7	88.8	90.1	.0632	2,288	16.2	2,032	14.62	....	12.98	....	Loam, gently sloping; season dry; one irrigation.
George, H. C., Okeana, Ohio.	1910	....	1,150	....	1,035	....	90	.2963	....	55.4	....	49.9	31.98	40.91	78.1	Clay loam; bottom land; season rather wet.
Goddard, W. R., Amesville, Ohio.	1910	....	360	(1)	336	....	93.3	.0606	....	84.9	....	79.2	29.40	39.37	74.8	Black clay, level; bottom land; very dry season.
Hansbarger, D., Ansonia, Ohio.	1910	(1)	6,060	....	6,023	....	99.4	8.22	....	105.4	....	101.8	37.06	36.97	100.2	Black, fairly loose soil, level; dry toward last of season.
Hester, H. C., Mayfield, Ky.	1910	[5] 330	250	180	210	54.5	84	.0482	6,850	74.1	3,730	62.2	49.65	48.63	102.1	Loose clay loam, level; no rain till roasting-ear stage; then very wet.
Heuser, W. L., Haymarket, Va.	1910	[2] 102	136	[2] 81	112	79.4	82.4	.0397	2,570	48.9	2,038	40.3	38.54	38.02	101.2	Red shale soil, level; wet early, dry later.

[1] Ripened earlier.

[2] No difference in the time of ripening.

[3] Ripened 3 days earlier.

[4] Ripened 5 days earlier.

[5] Ripened a few days earlier.

TABLE III.—*Results of experiments in corn tillage for the years 1905 to 1911, inclusive*—Continued.

Name and address of experimenter.	Year	Yield per plat.				Yield of uncultivated plat expressed as percentage of cultivated.		Size of plat.	Yield per acre (calculated).				Precipitation.			Remarks.
		Cultivated.		Uncultivated.					Cultivated plats.		Uncultivated plats.		Last 3 months of preceding and first 9 months of current year.	Mean.	Comparison with mean.	
		Fodder.	Grain.	Fodder.	Grain.	Fodder.	Grain.		Fodder.	Grain.	Fodder.	Grain.				
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*			*Acres.*	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Ins.*	*Ins.*	*P. ct.*	
Howle, P. L., Darlington, S. C.	1910	(1)	78.1	(1)	75.81	......	97.1	0.0744	......	15	......	14.56	39.53	47.20	83.8	Sandy, with clay subsoil; fairly good season.
Huyett, J. B., Charles Town, W. Va.	1910	(1)	323.6	(1)	225.5	......	69.7	.1398	......	33.1	......	23.08	27.52	37.43	73.6	Loam, with clay subsoil; extremely dry season.
Kirkpatrick, L. R., McKinney, Tex.	1910	......	448.7	(2)	308	......	68.4	.1687	......	38	......	26	27.71	49.96	55.6	Black loam; low bottom, extremely dry season.
Lambert, F. L., Charles City, Iowa.	1910	(1)	213.7	(1)	213.7	......	100	.0555	......	55	......	55	25.04	31.29	80.1	Sandy loam, level; dry at first; wet later.
Lemmon, R. H., Winnsboro, S. C.	1910	(1)	52	(1)	52	......	100	.0155	......	47.9	......	47.9	41.85	44.61	93.8	Sandy loam, slightly rolling; wet season.
Lloyd, F. L., Smithville, Ky.	1910	(2)	62.5	......	63.5	......	101.6	.01406	......	63.5	......	64.4	48.29	45.67	105.6	Heavy clay, rolling; wet season.
McClelland, C. K., Prescott, Ark.	1910	(2)	64.2	......	49.7	......	77.4	.0884	......	10.37	......	8.03	47.56	44.94	105.7	Heavy clay, nearly level; very dry most of season.
McCulloch, Fred, Hartwick, Iowa.	1910	77.5	213.5	75	202	96.8	94.6	......	......	......	......	......	25.43	34.48	73.9	Season very dry and hot.
McCune, Kate B., Shedd, Oreg.	1910	(1)	13	(1)	12	......	92.3	.00284	......	65.2	......	60.3	......	......	......	Clay loam; season very dry.
Marvin, Jas. A., Hendersonville, S. C.	1910	......	497	(2)	518	......	104.2	.297	......	23.9	......	24.9	47.84	50.02	95.6	Sandy soil, clay subsoil; latter part of season very wet.
Morgan, Geoffrey, Whites Station, Ky.	1910	[2] 650	705	700	820	107.7	116.3	.1027	6,330	98.1	6,820	114.1	50.22	44.02	114	Loam soil, clay subsoil; very wet season.
Nichols, W. D., Bloomfield, Ky.	1910	177	171	118	126	66.6	73.7	......	......	......	......	......	48.39	44.90	107.7	Clay loam, gently sloping; rather dry early, very wet later.
Perry, John B., Clarks Falls, Conn.	1910	[1] 364	320	[1] 368	323	101.1	100.9	.1077	3,376	42.45	3,415	42.82	36.89	46.18	79.9	Light loam, level; good season.
Ratliff, W. S., Richmond, Ind.	1910	126.5	92	114.5	114	90.5	123.9	.0313	4,040	42	3,656	52	37.62	38.49	97.8	Sandy loam, clay subsoil; rather dry season.
Rector, J. H., Cumberland Gap, Tenn.	1910	260	350	[2] 300	339	115.4	94.3	.0358	7,266	139.7	8,386	131.7	44.11	48.33	91.4	Clay soil, level; very wet season.
Rinehart, N. W., Union, Ohio	1910	(1)	545.5	(1)	459.5	......	84.2	.0745	......	104.6	......	88	32.63	36.55	89.4	Rich, black, level bottom.

Ross, Henry, Milford, Mich...	1910	[1] 490	450	[1] 445	445.3	90.8	99	.208	2,353	30.9	2,136	30.6	28.04	31.77	88.3	Clay loam, sloping; season rather dry.
Royse, Oscar, Shenandoah, Iowa.	1910	....	108.5	....	120.75	......	111.2	.0312	......	49.65	....	55.25	30.83	32.25	95.6	
Sugar Experiment Station, New Orleans, La.	1910	(1)	258	(1)	295.8	......	114.7	.1206	......	30.5	....	35	55.12	55.63	99.1	Heavy alluvial silt; average season except long drought in spring.
U. S. Plant Introduction Garden, Chico, Cal.	1910	(1)	52.5	(1)	46	......	87.6	.0603	......	12.4	....	10.9	21.84	23.39	93.4	Sandy loam, level; season very dry.
Welch, E. K., Northwood Center, N. H.	1910	[1] 243	187	[1] 329	236	135.4	126.2	.0379	6,410	70.5	8,670	89	29.59	39.82	74.3	Sandy loam, hilly; season rather dry.
Williams, D. W., Wauseon, Ohio.	1910	[1] 850	881	[1] 902.5	888.5	106.5	100.8	.1185	7,174	106.2	7,641	106.9	36.04	37.31	96.6	Clay and sand, good soil; season rather dry.
Winsor, B. E., Coventry, R. I.	1910	(1)	351.5	(1)	315	......	89.6	.0689	......	72.9	....	65.3	33.61	45.31	74.2	Sandy loam, hilly; season very dry.
Wollschlaeger, Gus, Boerne, Tex.	1910	(1)	452	(1)	448.7	......	99.3	.2712	......	23.78	....	23.6	19.73	31.42	62.8	Black waxy, level; season very dry.
Total..................	......	12,461	25,901.95	11,740.9	25,523.3	......	......	6.525	79,783	2,252.91	79,049	2,195.03	....	.....	.....	
Average..............	......	655.8	602.3	617.9	593.5	96.19	96.51	.1591	4,693	54.95	4,650	53.54	36.99	41.8	88.7	
Anderson, W. B., Velpen, Ind.	1911	(1)	1,040	(1)	1,014	......	97.5	.20	......	74.3	....	72.4	....	.....	......	Loose bottom land, level; very wet except in midsummer, when it was very dry.
Arlington Experimental Farm, Rosslyn, Va.	1911	982	824	1,110	608	113	73.9	.15	6,545	78.4	7,400	58	....	.....	......	
Brant, W. C., Ruffin, S. C.....	1911	910	565	925	590	101.6	104.4	.241	3,775	33.5	3,839	35	....	.....	......	Bottom land, level.
Dailey, S. C., North Baltimore, Ohio.	1911	1,200	1,270	[3] 1,160	1,185	96.6	93.3	.471	2,550	38.5	2,460	35.9	....	.....	......	
Day, A. P., West Kennebunk, Me.	1911	[1] 578	705	[1] 462.5	485	80	68.8	.1856	3,115	54.3	2,495	37.35	....	.....	......	
Dimond, O. C., West Concord, N. H.	1911	[1] 692	547	[1] 598	539	86.4	98.5	.1202	5,756	65	4,972	64	....	.....	......	Strong, stony loam, on top of hill sloping; dry until midsummer, later part of season wet.
Elmer, E. O., Devereaux, Mich.	1911	[1] 218	337	[1] 252	365.5	115.6	108.4	.0757	2,880	63.6	3,330	68.9	....	.....	......	Sandy loam, level; early part of season dry, later part wet.
Goddard, W. R., Amesville, Ohio.	1911	(1)	562	(1)	596	......	106	.1234	......	65	....	68.9	....	.....	......	Limestone bottom, level; season very dry.
Hester, H. C., Mayfield, Ky..	1911	300	150	120	80	40	53.3	.3025	992	7.1	397	3.78	....	.....	......	Rolling land; season extremely dry.
Heuser, W. L., Haymarket, Va.	1911	[1] 182	223.5	[1] 168	254	92.3	113.9	.0804	2,263	39.7	2,089	45.25	....	.....	......	Sandy loam, drained bottom; early part of season dry.
Hill, L. E., Walterboro, S. C..	1911	....	250	(2)	220	......	88	.317	......	11.26	....	9.92	....	.....	......	Light soil, level; season dry.
Housekeeper, G. C., Bowling Green, Ohio.	1911	....	681	(3)	675	......	99.1	.1061	......	91.7	....	90.8	....	.....	......	Sandy loam, level; season very favorable.

[1] No difference in time of ripening.

[2] Ripened earlier.

[3] Ripened a few days earlier.

TABLE III.—*Results of experiments in corn tillage for the years 1905 to 1911, inclusive*—Continued.

Name and address of experimenter.	Year.	Yield per plat.				Yield of uncultivated plat expressed as percentage of cultivated.		Size of plat.	Yield per acre (calculated).				Precipitation.			Remarks.
		Cultivated.		Uncultivated.					Cultivated plats.		Uncultivated plats.		Last 3 months of preceding and first 9 months of current year.	Mean.	Comparison with mean.	
		Fodder.	Grain.	Fodder.	Grain.	Fodder.	Grain.		Fodder.	Grain.	Fodder.	Grain.				
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*			*Acres.*	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Ins.*	*Ins.*	*P. ct.*	
Huyett, J. B., Charles Town, W. Va.	1911	444.5	614	432	529	97.3	86.1	0.152	2,923	57.7	2,848	49.7	....	......	....	Loam, clay subsoil; season fairly favorable.
Ladd, E. O., Old Mission, Mich.	1911	[1] 817	595	[1] 787	758	96.3	127.4	.2635	3,100	32.24	2,985	41.08	....	......	....	Dark sandy loam, level; season cold, but enough rain.
Lambert F. L., Charles City, Iowa.	1911	(1)	180	(1)	180	....	100	.0389	....	66.1	....	66.1	....	......	....	Sandy loam, level; early part of season dry, later part wet.
Lemmon, R. H., Winnsboro, S. C.	1911	(1)	66	(1)	54	....	81.8	.0275	....	34.3	....	28.05	....	......	....	Fine sandy soil, rolling land; season very dry.
McClenden, S. E., Calhoun, La.	1911	....	149	....	140	....	93.9	.0965	....	22.06	....	20.72	....	......	....	Land almost level; good season, except dry in May.
McCulloch, Fred, Hartwick, Iowa.	1911	306	232	[2] 302	206	98.7	88.8	.0231	13,220	143.1	13,050	127	....	......	....	Heavy black loam, level; season very dry.
Perry, J. B., Clarks Falls, Conn.	1911	278	182	198	156	71.2	85.7	.0442	6,290	58.8	4,480	50.4	....	......	....	Loam, gravelly subsoil, level; extremely dry season.
Prince, A. H., San Augustine, Tex.	1911	(1)	216	(1)	216	....	100	.1147	....	26.9	....	26.9	....	......	....	Sandy loam, level; on top of hill; too wet to cultivate; then too dry.
Ransom, E. R., Blandville, Ky.	1911	10	52	[3] 10	48	100	92.3	.0138	724	53.8	724	49.7	....	......	....	Rich clay in garden, level; dry and hot in summer.
Rector, J. H., Cumberland Gap, Tenn.	1911	....	840	(2)	710	....	84.5	.1808	....	66.4	....	56.1	....	......	....	Clay loam, level; season very dry.
Seymour, R. R., Henning, Ill.	1911	....	460	....	380	....	82.6	.1683	....	39.05	....	32.25	....	......	....	Silt loam, level; May to August dry.
Smith, C. S., Nokesville, Va.	1911	[1] 61.5	70.5	[1] 58	67	94.3	95	.0301	2,040	33.41	1,925	31.75	....	......	....	Clay, level; season very dry until July 20.

U. S. Plant Introduction Garden, Chico, Cal.	1911	212	86	[2] 181	74	85.3	86	.0482	4,418	25.52	3,770	21.95	....	......	....	Sandy loam, level; season dry.
Total		7,191	10,897	6,763.5	10,129.5	....	....	3.5745	60,591	1,281.74	56,764	1,191.9	....	......	....	
Average	......	479.4	435.9	450.9	405.2	91.24	92.37	.1429	4,039	51.27	3,784	47.67	....	......	....	

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[1] No difference in time of ripening.

[2] Ripened earlier.

[3] Ripened a few days earlier.

RÉSUMÉ OF THE CORN-CULTIVATION EXPERIMENTS.

Table IV presents a résumé of all the experiments. The yield of the uncultivated plat is expressed as a percentage of the yield of the cultivated plat. The average percentages shown in Tables I and III are here compiled for comparison. Of the total number of 125 tests whose data are recorded in this bulletin, 1 test shows fodder yields only, 54 tests show yields of both fodder and grain, and 70 tests show grain yields only. The data on grain yields are, therefore, given for 124 and on fodder yields for 55 of the total number of experiments. The general average for all the experiments shows that the fodder on the uncultivated plats was 95.1 per cent of the cultivated and that the uncultivated grain was 99.108 per cent of the cultivated.

TABLE IV.—*Résumé of average results of experiments in corn tillage.*

Designation of experiments.	Fodder.		Grain.	
	Number of experiments.	Average yield of uncultivated plats expressed as percentage of cultivated.	Number of experiments.	Average yield of uncultivated plats expressed as percentage of cultivated.
Early experiment station work (Table I)	2	85.35	12	98.5
1905 and 1906 (Table III)	3	96.36	5	108.4
1907 (Table III)	2	91.6	8	110.84
1908 (Table III)	4	94.95	6	97.93
1909 (Table III)	10	101.15	25	105.27
1910 (Table III)	19	96.19	43	96.51
1911 (Table III)	15	91.24	25	92.37
Total	55		124	
General average		95.1		99.108

GEOGRAPHICAL DISTRIBUTION OF THE EXPERIMENTS.

Figure 8 shows the distribution of the experiments in the various States. It will be noted that the conditions of soil and climate under which the tests were made are quite varied. The total number of experiments recorded in the summary is 125 and the number of States represented in this work 28. In Table V the location of the experiments by States is correlated with the average yield of grain from the uncultivated plats expressed as a percentage of the average yield of grain from the cultivated plats.

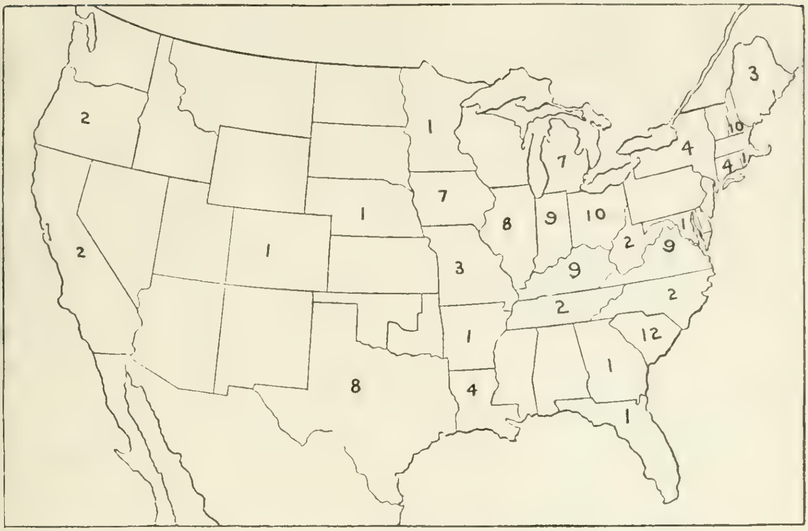

FIG. 8.—Map showing the distribution of the corn-cultivation experiments in the various States.

TABLE V.—*Relative grain yield by States.*

State.	Number of experiments.	Average yield of uncultivated plats expressed as percentage of cultivated.	State.	Number of experiments.	Average yield of uncultivated plats expressed as percentage of cultivated.
Arkansas	1	77.4	Missouri	3	103.2
California	2	86.8	Nebraska	1	101.9
Colorado	1	90.1	New Hampshire	10	112.71
Connecticut	4	98.8	New York	4	104.7
Florida	1	87.1	North Carolina	2	92.15
Georgia	1	138.8	Ohio	10	96.17
Illinois	8	94.74	Oregon	2	99.3
Indiana	9	105.36	Rhode Island	1	89.6
Iowa	7	102.72	South Carolina	12	99.07
Kentucky	9	91.28	Tennessee	2	89.4
Louisiana	4	105.8	Texas	8	92.59
Maine	3	77.9	Virginia	9	88.51
Maryland	1	109.2	West Virginia	2	77.9
Michigan	7	116.26			
Minnesota	1	100	Total	125	

RELATIVE MATURITY OF CULTIVATED AND UNCULTIVATED CORN.

In 1909, 1910, and 1911 the cooperators were asked to report which of the two plats or sets of plats matured first. Note of this matter was made by 68 of them, 39 of whom reported no difference in the date of ripening, while 10 stated that the cultivated plats ripened first and 19 stated that the uncultivated plats were first to ripen. The average grain yield from the uncultivated plats expressed as a percentage of the yield from cultivated plats in these three groups is approximately 100 per cent for the first two groups and 95.58 per cent for the third group. These results are shown in Table VI, and they seem to indicate that when for any reason the uncultivated plat falls below the cultivated plat in yield the uncultivated corn has a tendency to mature earlier than the cultivated corn.

TABLE VI.—*Relative time of maturity of cultivated and uncultivated corn.*

Relative time of maturity.	Number of experiments.				Average grain yield of uncultivated expressed as percentage of cultivated.
	1909	1910	1911	Total.	
Cultivated ripened first	3	7	0	10	100.36
No difference in time of ripening	11	18	10	39	101.68
Uncultivated ripened first	3	9	7	19	95.58
Total	17	34	17	68	

RELATION OF CORN-TILLAGE RESULTS TO RAINFALL.

In the annual charts of the experiments, with the exception of the year 1911, for which the data are not yet available, are given the actual rainfall, the mean rainfall, and the actual rainfall expressed as a percentage of the mean. As previously stated, this rainfall is for the last three months of the previous year and for the first nine months of the year in which the experiment was conducted. Rainfall data are available for 95 of the 124 experiments. Of the whole series of experiments the lowest rainfall with reference to mean was 42 per cent and the highest 133 per cent. In two experiments a rainfall of over 120 per cent of the mean was recorded, while in three experiments the rainfall was less than 60 per cent of the mean. Working out the relation between the yield of the uncultivated plats expressed in percentage of the yield of the cultivated plats and the rainfall expressed in terms of percentage of the mean rainfall, there was found to be a correlation of only 0.142 ± 0.065, which can not be considered significant.

In actual rainfall the lowest precipitation for any experiment was 16 inches for the year and the highest 61 inches. The greater number of the experiments upon which rainfall data are presented received from 30 to 40 inches of rain for the period. Working out the correlation between the yield of the uncultivated plat, expressed in percentage of the cultivated, and the actual rainfall, there was found to be a correlation of only 0.0188 ± 0.067.

These data do not indicate that rainfall enters into the problem to any appreciable extent

RELATION OF CORN-TILLAGE RESULTS TO SOIL PRODUCTIVITY.

The results of all the tillage experiments were studied with the object of determining whether the factors which influence grain yield had any effect on the yield of uncultivated corn as compared with the cultivated. For this purpose the experiments were considered in three groups: Group 1, containing those experiments in which the yield on the cultivated plats fell below 30 bushels per acre; group 2, those varying from 25 to 60 bushels; and group 3, those above 50 bushels. By thus overlapping the limits of the various groups it was thought that tendencies would be shown more clearly than if absolute limits were observed.

Little evidence is shown that any relation exists between these two factors. Group 1, containing the lowest grain yields, shows the average yield on the uncultivated plats to be 97.19 per cent of that on the cultivated; group 2 shows 99.59 per cent; and group 3 shows 98.34 per cent. The details are given in Table VII.

Table VII.—*Relation of corn-tillage results to soil productivity.*

Year.	Experimenter.	Yield of cultivated plat per acre.	Yield of uncultivated plat expressed as percentage of cultivated.
	Group 1.—*Yields less than 30 bushels per acre.*		
		Bushels.	
1906..	New Hampshire experiment station....	23.3	141.6
1908..	North Carolina experiment station.........	11.55	92
1909..	Callison, N. A..........	25.3	87.1
	Campbell, J. M.........	12.2	66.8
	Cunningham, T. J.....	22.5	115
	Foster, W. L..........	16.6	114.7
	Rich, E. A. J..........	26.7	138.8
	Seay, Robert..........	29.7	80.6
	Sugar Experiment Station...............	20.6	100
	Wollschlaeger, Gus....	19.2	101.7
1910..	Campbell, J. M..........	24	107.1
	Crum, H. C............	21	114.3
	Ferguson, A. M........	5.67	95.9
	Gardner, E. T.........	16.2	90.1
	Howle, P. L...........	15	97.1
	Marvin, Jas. A.........	23.9	104.2
	McClelland, C. K......	10.37	77.4
	U. S. Plant Introduction Garden..........	12.4	87.6
	Wollschlaeger, Gus....	23.78	99.3
1911..	Hester, H. C..........	7.1	53.3
	Hill, L. E.............	11.26	88
	McClendon, S. E......	22.06	93.9
	Prince, A. H..........	26.9	100
	U. S. Plant Introduction Garden.........	25.52	86
	Average.........	....	97.19
	Group 2.—*Yields between 25 and 60 bushels per acre.*		
		Bushels.	
1886..	New York experiment station (Geneva)....	56.8	124.1
1890..	Missouri experiment station...............	54	84.6
1891..	Illinois experiment station...............	58.4	94.7
1893..	.....do................	36.3	79
1898..	South Carolina experiment station........	58.6	96.4
1906..	Purdue experiment station...............	46.97	95.9
1907..	Cornell experiment station...............	50.3	103.4
1908..	Arlington Experimental Farm.............	41.4	97.7
1909..	Anderson, W. B......	48.1	136.5
	Barrett, J. M..........	52.2	123.7
	Arlington Experimental Farm.............	30.6	74.1
	Callison, N. A	25.3	87.1
	Lambert, F. L........	56.4	115.3
	Leffler, G. V..........	40.5	109.6
	Perry, J. B............	45.7	108.7
	Purdue experiment station...............	42	100.25
	Rich, E. A. J..........	26.7	138.8
	Seay, Robert..........	29.7	80.6
	Tenney, W. P.........	31.25	170.5
1910..	Bigstaff, T. J..........	37.65	96.6
	Day, A. P..............	47.9	87
	Finley, W. W.........	48.8	92.3
	Fredericks, C. P.......	50.14	106.4

TABLE VII.—*Relation of corn-tillage results to soil productivity*—Continued.

Year.	Experimenter.	Yield of cultivated plat per acre.	Yield of uncultivated plat expressed as percentage of cultivated.
	GROUP 2.—*Yields between 25 and 60 bushels per acre*—Cont'd.		
		Bushels.	
1910	George, H. C	55.4	90
	Heuser, W. L	48.9	82.4
	Huyett, J. B	33.1	69.7
	Kirkpatrick, L. R	38	68.4
	Lambert, F. L	55	100
	Lemmon, R. H	47.9	100
	Perry, J. B	42.45	100.9
	Ratliff, W. S	42	123.9
	Ross, Henry	30.9	99
	Royce, Oscar	49.65	111.2
	Sugar Experiment Station	30.5	114.7
1911	Brant, W. C	33.5	104.4
	Dailey, S. C	38.5	93.3
	Day, A. P	54.3	68.8
	Heuser, W. L	39.7	113.9
	Huyett, J. B	57.7	86.1
	Ladd, E. O	32.24	127.4
	Lemmon, R. H	34.3	81.8
	Perry, J. B	58.8	85.7
	Prince, A. H	26.9	100
	Ransom, E. R	53.8	92.3
	Seymour, R. R	39.05	82.6
	Smith, C. S	33.41	95
	U. S. Plant Introduction Garden	25.52	86
	Average	....	99.59
	GROUP 3.—*Yields more than 50 bushels per acre.*		
1886	New York experiment station (Geneva)	56.8	124.1
1888	Illinois experiment station	93.8	95.9
1889	do	84.6	91.1
1890	do	66.8	103.4
1891	do	58.4	94.7
1892	do	70.1	109.5
1896	do	85.5	101.7
1889	Missouri experiment station	80.1	101.3
1890	do	54	84.6
1898	South Carolina experiment station	58.6	96.4
1899	do	67.3	100.3
1907	Cornell experiment station	50.3	103.4
	Froley, J. W	65.3	109.2
	Nebraska experiment station	61.9	101.9
	Purdue experiment station	77	103.7
	GROUP 3.—*Yields more than 50 bushels per acre*—Cont'd.		
		Bushels.	
1908	Minnesota experiment station	62.5	100
	New Hampshire experiment station	67.9	100.4
	Purdue experiment station	62.5	96
1909	Barrett, J. M	52.2	123.7
	Dimond, O. C	62.4	121.1
	Lambert, F. L	56.4	115.3
	Lee, J. J	81.3	96
	Littlejohn, W. D	73.8	95.3
	McCune, Kate B	107.4	106.3
	Merwin, G. H	78.4	100
	Sawyer, R. S	71.3	69.1
	Wallace, M	84.9	91.9
	Watson, A. D	67.4	99.1
	Welch, E. K	64.2	109.7
1910	Anderson, W. B	62.6	99.2
	Brant, W. C	70.3	95.5
	Case, J. H	65	107.7
	Dailey, S. C	83.1	89.2
	Dimond, O. C	90.6	90.9
	Elmer, E. O	85.6	101.8
	Fredericks, C. P	50.14	106.4
	George, H. C	55.4	90
	Goddard, W. R	84.9	93.3
	Hansbarger, D	105.4	99.4
	Hester, H. C	74.1	84
	Lambert, F. L	55	100
	Lloyd, F. L	63.5	101.6
	McCune, Kate B	65.2	92.3
	Morgan, Geoffrey	98.1	116.3
	Rector, J. H	139.7	94.3
	Rinehart, N. W	104.6	84.2
	Welch, E. K	70.5	126.2
	Williams, D. W	106.2	100.8
	Winsor, B. E	72.9	89.6
1911	Anderson, W. B	74.3	97.5
	Arlington Experimental Farm	78.4	73.9
	Day, A. P	54.3	68.8
	Dimond, O. C	65	98.5
	Elmer, E. O	63.6	108.4
	Goddard, W. R	65	106
	Housekeeper, G. C	91.7	99.1
	Huyett, J. B	57.7	86.1
	Lambert, F. L	66.1	100
	McCulloch, Fred	143.1	88.8
	Perry, J. B	58.8	85.7
	Ransom, E. R	53.8	92.3
	Rector, J. H	66.4	84.5
	Average	....	98.34

SIMPLIFICATION OF WEED CONTROL WHEN THE SOIL IS NOT STIRRED.

A very interesting observation made during these investigations is that with some of the experiments on certain soils weeds ceased growing on the uncultivated plats sooner than on the cultivated ones, where the number of hoeings and cultivations, respectively, was the same; so that at harvest time the uncultivated plats were quite free from weed growth and the cultivated plats were more or less weedy. An example of this is shown in figure 9, which illustrates a carefully conducted experiment on a rather stiff clay soil at the Arlington Experimental Farm. On the uncultivated plats of this experiment the weeds started growing immediately after planting to about the same extent as on the cultivated plats. But as the season progressed and the weed seeds in the surface inch or two of soil germinated and the seedlings were destroyed, the weed growth became gradually less, while on the cultivated plats the weeds continued to grow thriftily throughout the season. This tendency was shown in a number of experiments on soils of this kind. The reason for this may be due to the condition of the soil on the uncultivated plats discouraging germination of weed seeds beneath the surface inch or two and the inability of the seedlings to push up through the hard crust, whereas on the cultivated plats the friable surface soil permitted the seedlings to push up from a considerable depth and the tillage implements were constantly bringing up weed seeds into the surface soil where conditions were more conducive to germination.

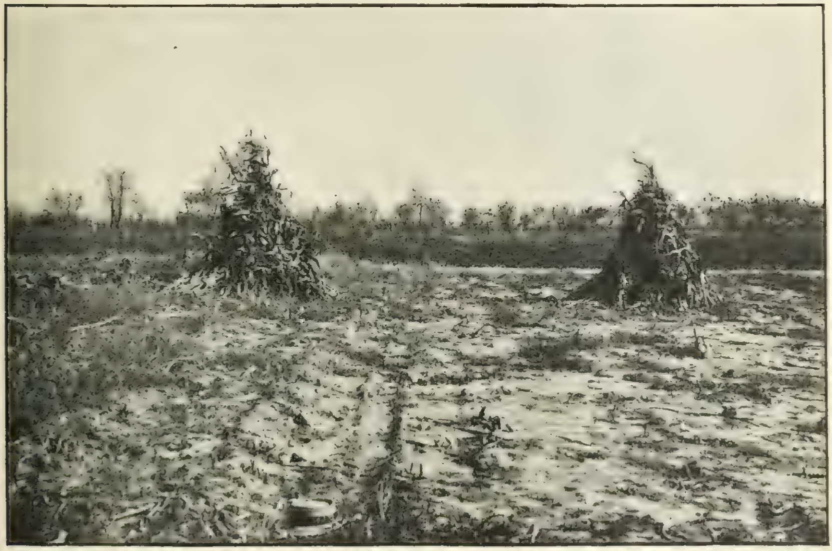

FIG. 9.—Two plats at the Arlington Experimental Farm, the cultivated at the left and the uncultivated at the right, showing the difference in weed growth under the two methods of treatment.

It was observed that on other soils, however, especially those of a loose, deep, moist character, the weed growth on the two sets of plats was about the same throughout the season.

Whether or not it is desirable to discourage the germination of weed seeds can not be stated definitely at the present time. It may be argued on the one hand that the crop should be so tilled as to induce the germination of as many of the weed seeds as possible, with the subsequent destruction of the seedlings. On the other hand it may be argued that under the conditions that existed on the nontilled plats of these experiments, although a much smaller proportion of weed seeds in the soil was induced to germinate, many of those that remained ungerminated probably lost their viability and that as there was a much smaller number of weeds on these plats than where the land was tilled a correspondingly less number of weed seeds matured to reseed the land in the latter part of the season after cultivation stopped.

It must be understood that there are no data to prove which of the two opinions stated above is the correct one. It is impossible to say, therefore, which of the two methods of treatment would be the less conducive to weediness of the soil through a period of years during which different crops were grown. The observations on these experiments, however, seem to indicate that for the years in which the land is in cultivated crops the work of weed control may be considerably simplified by shallow rather than deep working of the soil.

FAIRNESS OF THE TESTS.

Although the weed growth seemed to be less on the uncultivated plats than on the cultivated ones in some of the experiments, there were others where the surface scrapings or hoeings were not sufficient to keep down the weeds as thoroughly on the uncultivated plats as on the cultivated ones. It is believed, therefore, that on an average for all experiments the weed growth under the two kinds of treatment was about the same in extent, but that if there was any difference in this regard there were more weeds on the uncultivated than on the cultivated plats—due to the fact that some of the cooperators did not do as thorough work in keeping down weeds on the uncultivated plats as on the cultivated ones.

Another point which may have affected the fairness of the tests was that where the experiments were located on sloping land there was a tendency for rain water (especially at times of heavy rains) to run off the uncultivated plats to the adjoining cultivated ones, where it was caught and allowed to soak in the soil, on account of the rough and absorptive condition of its surface, so that the cultivated plats received more than their share of the precipitation.

Altogether, if there was any advantage in favor of either of the sets of plats it was on the side of the cultivated ones.

RELATION OF TESTS SHOWN BY FREQUENCY CURVE.

The frequency curve (fig. 10) shows that the results secured are not of a mere haphazard nature. Of the total number of experiments 46 per cent give results between 92.5 and 107.5 per cent of uncultivated grain in terms of the cultivated. These limits come well within the bounds of experimental error. The general average, therefore, of the whole 124 tests, showing 99.108 per cent as much grain produced on the weeded plats as on cultivated plats, is significant.

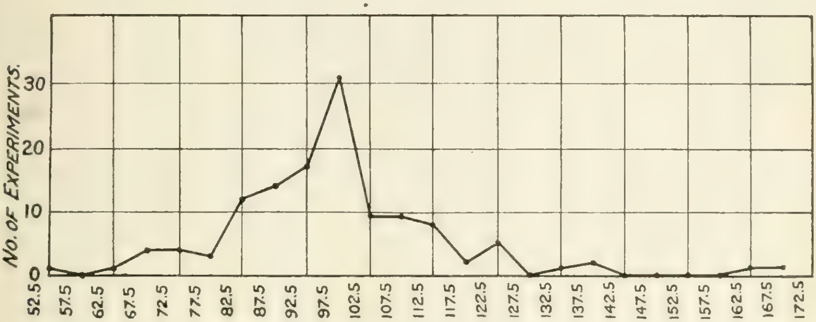

FIG. 10.—Diagram showing the yields of uncultivated plats of corn expressed in percentages of yields of cultivated plats for 124 experiments in 28 States.

INTERPRETATION OF THE RESULTS OBTAINED.

The reasons why uncultivated land kept free from weeds should yield practically as much corn (grain) per acre as that given the most approved modern cultivation are not clear. The results, however, point strongly to the conclusion that the principal object of cultivation is the destruction of weeds. Where the weeds are kept down by some other method cultivation seems to be of no particular advantage. This is contrary to the accepted teaching on this point, and the conclusion is stated only tentatively. There have been abundant experimental results to show that when land is fallow a soil mulch upon it tends to preserve the moisture in the soil. It appears quite possible that when the soil is fully occupied by the roots of a growing crop there is little possibility of moisture from the deeper layers of the soil being drawn by capillary action to the surface, where it could be evaporated, for in doing so the moisture would have to thread its way through a maze of roots eager to absorb it. Does it not seem that these roots would themselves play the part that a soil mulch would play if the roots were not there? If such is the case, what additional advantage would arise by having a mulch on a surface beneath which is a tangle of fine roots capable of absorbing any moisture that might try to pass upward to the surface?

On the other hand, these roots would not interfere to any great extent with the progress of rain water downward in the soil, for when rainfall is great enough to saturate the surface soil there would be more moisture present than the roots could absorb. Thus, while the soil mulch is important on fallow soils as a means of holding moisture, is it not possible that a soil well filled with living plant roots is not in need of a mulch for this purpose? This would at least be a plausible explanation of the results reported in this bulletin.

It is further suggested that these results may partly be due to the fact that tillage mutilates the surface roots of the crop. Again, a fall of rain too light to moisten the soil below the depth of stirring would all be lost on the cultivated land because it would not reach the roots of the crop, while on the weeded plat there would be enough roots in the surface soil to absorb a considerable proportion of such light rainfall before it had time to evaporate.

While the suggestion that the presence of a maze of living roots in the soil would itself, to a large extent, prevent loss of moisture by evaporation at the surface, it is not proved that this is the case. We must therefore consider other possibilities. Even with ordinary methods of cultivation there would be some loss of moisture at the surface, for tillage itself would expose a large amount of moist soil to the atmosphere, so that in any case a growing crop would hardly utilize all the rainfall that occurs during a growing season. If, however, the loss of moisture by evaporation is greater on the uncultivated plats than on the cultivated ones it is possible that this would be compensated for by a correspondingly greater amount of nitrates and other soluble salts being brought up from the deeper layers of the soil to the surface, thus furnishing a greater quantity of plant food for the corn roots.

It should be clearly understood that the writers offer these remarks merely as suggestions. The underlying causes for the phenomena observed must be left for future determination.

PRACTICAL SIGNIFICANCE OF THE RESULTS.

An explanation of the results obtained in these experiments is of secondary importance as compared with the interpretation we shall give them from a practical standpoint. The results as a whole come well within the limits of experimental error, showing no more difference in yield between the weeded plats and those receiving normal cultivation than might be expected between two series of 125 plats treated exactly alike.

Table V shows the results of the experiments by States. As only a small number of experiments have been conducted in some States, it is probable that another set of tests would show considerable difference in results in many localities. It would not be advisable, therefore, to make practical suggestions for any particular locality based on the indications of these results as a whole without first making actual tests to see whether under local conditions these same principles will govern. Where these results are found to hold good, however, two entirely new fields of research are opened up, and their practical importance to the corn growers of America from a labor and money saving standpoint is not to be gainsaid.

If it be true that weeds make the cultivation of corn necessary the problem immediately presents itself as to what farm-management methods can be pursued to eliminate or reduce to a minimum the weed pests of the farm. In this connection we have (1) the problem of what may be termed persistent perennial weeds. Among this group may be mentioned Johnson grass, quack-grass, Bermuda grass, wild morning-glory, Canada thistle, wild onion, and horse nettle. Publications already issued by the Department of Agriculture deal with the control of these pests. In the main these weeds require special treatment to eradicate them. We have (2) the biennial and annual weeds, which are troublesome largely through their prolific seed habits. As a class these weeds should be prevented from going to seed until all the seeds infesting the land shall have germinated and the seedlings have been destroyed.

Our present implements for cultivation are designed primarily to produce a mulch and stir the ground. Weed killing is a secondary function. It is possible that newly designed implements made with special reference to weed control could accomplish this end with greatly decreased cost. The weeder will probably be considered of vastly more importance than heretofore when more data with reference to its use are available.

Another large field of investigation in connection with weed control is of much practical importance to the farmer. This field of work might be outlined as a study of those systems of farming or rotations which are especially calculated to lessen the weed pests on the farm. It is a well-known fact that certain rotations of crops bring us round to the tillage crop with the land practically free from weed pests. One experiment is reported where a piece of sod land very free from everything but clover and timothy was put to corn and no cultivation given, as no weeds were present; a crop of 70 bushels per acre was produced. In some sections of the South, where a 1-year rotation of corn and crimson clover is practiced, the weeds are reduced to a minimum and many farmers cultivate corn on such land only once and secure large yields. Studies are being conducted on this problem of adapting cropping systems to weed control, and more data will be at hand at a later date.

Just what implements are best to destroy weeds when present and just what rotations should be practiced to control them are largely local problems. Each State or agricultural region will have its own answer. In those cases where a soil mulch may be desirable it will undoubtedly be true that any tillage implements designed primarily to kill weeds will incidentally produce a sufficient soil mulch to answer all requirements in this respect.

The writers interpret the results here presented to mean that weeds are in the main the enemy which makes cultivation necessary. The exceptions should be determined by further work. Weeds can be fought from two standpoints: (1) With tillage implements specially designed to kill these pests instead of to stir the soil and make a mulch and (2) from the standpoint of rotations especially designed to overcome the weeds of the particular locality. It is believed that by adopting methods in conformity with this point of view the weed problem will be simplified and in all probability the cost of cultivation will at the same time be greatly decreased.

SUMMARY.

A number of tests made at several agricultural experiment stations seem to indicate that it is the weed factor that makes the cultivation of corn necessary, or, stating the proposition conversely, that cultivation is not beneficial to the corn plant except in so far as removing the weeds is concerned.

The subject of weed control is recognized as a fundamental one in tillage philosophy. It was therefore determined to carry on, over a wide range of climatic and soil conditions, a large number of tests of the relative yields of corn produced by supposedly optimum cultivation as compared with mere weed elimination.

The experiments were made by having two plats or sets of plats, one of which received no cultivation after planting, the weeds being kept down by a horizontal stroke of a sharp hoe at the surface of the soil, particular care being taken not to disturb the soil or to form a soil mulch; the other set of plats received the usual cultivation.

This work was carried on by the Department of Agriculture for six years (1906 to 1911) in cooperation with several State agricultural experiment stations and with farmers, many of whom were graduates of agricultural colleges. The results of 125 experiments are recorded in this bulletin, including the early experiment-station tests. The seven years' work in Utah is given separate discussion. Of the 125 experiments 124 record grain yields and 55 give fodder yields.

A general average of all of these experiments shows that the weeded plats produced 95.1 per cent as much fodder and 99.108 per cent as much grain as the cultivated ones. If there was any difference between either set of plats in regard to thoroughness in keeping down weeds it was in favor of the cultivated plats.

Although it remains to be demonstrated how far this principle may be applied in any particular section, as a general average for all the regions in which this work was done it may be concluded that the proposition just stated is substantially true. If this be accepted, weed control becomes the principal object of cultivation.

Weeds may be attacked in two ways: (1) By the use of tillage implements, the primary purpose of which is their eradication, and (2) by adopting cropping systems having that object in view.

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SOME NEW ALFALFA VARIETIES FOR PASTURES.

BY

George W. Oliver, *Plant Breeder and Propagator.*

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., June 1, 1912.

Sir: I have the honor to transmit herewith a manuscript entitled "Some New Alfalfa Varieties for Pastures," by Mr. George W. Oliver, Plant Breeder and Propagator, and recommend that it be published as Bulletin No. 258 of the series of this bureau.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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SOME NEW ALFALFA VARIETIES FOR PASTURES.

INTRODUCTION.

The lines of investigation worked out in this paper were briefly outlined to the writer a few years ago by Dr. B. T. Galloway. The material experimented with includes numerous plants of the Grimm, Turkestan, Baltic, and Mongolian alfalfas, obtained from many sources, including the strains raised by Prof. W. A. Wheeler, of South Dakota, and the selections of hardy plants made by Mr. John M. Westgate and Mr. Charles J. Brand, of the Bureau of Plant Industry. The valuable collections obtained in foreign countries by Mr. Frank N. Meyer, one of the agricultural explorers of the Bureau of Plant Industry, and the plants selected abroad by Prof. N. E. Hansen, of the South Dakota State College of Agriculture, have all been utilized in breeding new races of alfalfa.

The first work undertaken with the large amount of material available was to become familiar with the characters peculiar to each of the widely different groups. During the progress of this investigation important characters were found which in the different groups seem correlated with hardiness and drought resistance. These characters consist of the underground development of rhizomes and modified rhizomes.

In the numerous crosses which have been made at the Department of Agriculture during the last three summers much attention has been given to these underground characters, because the alfalfa which has a root system that assures hundreds of resting buds, in some cases no less than 12 inches below the surface of the soil, is the variety which may be expected to withstand semiarctic conditions. Other plants with very large succulent rhizomes several feet in length evidently function during protracted dry spells partly through their storage of water.

A large number of crosses have been developed, in most cases only to the first generation. Many of the plants have been fruited and seedlings of the second generation raised. The principal object in making these crosses is not so much the improvement of the strains now growing in this country as it is to provide strains adapted to pasturage which will succeed in the large areas where alfalfa is not grown at all.

In so far as the project has progressed, the outcome is highly promising. The Department of Agriculture, however, has as yet nothing to distribute and will not have until the crosses are an assured success in the areas referred to.

During the study of perhaps the largest number of what are considered distinct species and forms ever brought together in a single collection, it becomes evident that until recently very little has been ascertained concerning the life history of the alfalfas of the world. They are a much mixed lot of plants, as scarcely any of them, even when gathered in localities where they seem to be native, come invariably true from seed. This unfortunate condition is due to the cross-pollination of the flowers by insects, but it is possible to breed them to come true to type, and the result is worth the effort necessary to accomplish it.

During the progress of the initial stages of breeding alfalfa for different sections of the country it became evident that the extensive rhizome development of some of the wild forms, so far as the writer has been able to ascertain, has never been taken into consideration in hybridizing work to perfect hardy and drought-resistant strains. The hybrid combinations are startling in their abundant growth, both above and below ground. This bulletin has been written partly to call attention to these characters and partly to place on record a number of crosses already made.

PROVISION FOR THE PERPETUATION OF TYPES IN ALFALFAS COMPARED WITH COWPEAS.

In the first generation of a cross between two varieties of the cowpea each plant is like its neighbor, and no difference can be detected in, say, 12 plants, which number is frequently secured in a single cross. The habit of growth, color, size, and shape of pod and the color, size, and shape of seeds are in each case alike. The flowers of the parents are self-pollinating and the plants of a fixed variety come true from seed, because each stigma is pollinated with the pollen of its own flower. When, however, the flowers of two plants are crossed and these two plants are dissimilar in many or few characters, such as spreading and upright habits, and the seeds are different in their markings, one, for instance, being white with a black eye and the other speckled like the Whippoorwill variety, the progeny in this first generation will have black seeds. In the second generation the color combinations, also the size and form of seed, are numerous;

sometimes in as many as 16 series of plants observed the seeds of any one series are entirely unlike those of the other 15. In the next sowing the seeds of each plant of the second generation are sown separately and only those in this, the third, generation which resemble those of the second are again saved. If they continue to come true in the next, or the fourth, generation, they will always come true.

With alfalfas, however, a very different problem is presented, in that very often the parents selected do not come true even from seeds resulting from flowers which have been self-pollinated. The reason for this is that the flowers are perfectly constructed for intercrossing. A seed parent selected for crossing sometimes gives over a dozen distinct forms when inbred. All of these when inbred again do not come true, but occasionally a plant will be found which has the characters of the original plant. This absolutely essential preparation for crossing requires at least two seasons before one can be reasonably certain that he has parents which are fixed enough in the desired characters to begin hybridizing.

THE ALFALFAS OF NORTHERN AFRICA.

Dr. B. T. Galloway, while abroad last year, discovered a large number of alfalfas in flower, many of which looked promising, none of which he had seen in the United States. Later in the summer, seeds of all these plants were collected by the writer, chiefly in northern Africa. Most of them were found in abandoned patches of exceedingly poor soil at one time cultivated by Arabs. The manner of their occurrence suggests that they are introduced rather than native species. Whatever their origin, more species and forms of alfalfa occur in northern Africa than have been reported in any other region of the world.

Most of these forms have never been tried on American farms. Some of the plants from which seeds were imported are puzzles in a botanical classification. Among the number there are tall, strictly upright forms with glutinous hairs and large yellow flowers which perhaps belong to the form known as *Medicago sativa glutinosa*. Others of this class have bluish green flowers, between those of *M. sativa glutinosa* and *M. sativa glandulosa*. Some again have falcate pods studded with glandular hairs, probably crosses between *M. falcata* and *M. sativa glutinosa*. Some plants of exceedingly upright growth and showing every indication of being typical *M. sativa* had the telltale glandular pubescence on the pods. Some of these plants have more seeds to the individual than any hitherto recorded. Seedlings from all these plants, including 49 forms, are now growing at Washington and they will be used shortly on a small scale for testing, so that a study can be made of them as a basis for future hydridizing.

A plant which seems to be nearest *Medicago sativa gaetula* was found a few miles west of Algiers. This plant has longer rhizomes than any other wild alfalfa received by the Department of Agriculture. Some rhizomes developed on a specimen brought to Washington which are over 3 feet 6 inches in length. (Pl. I, fig. 1.) One plant observed covered an area of fully 9 square feet. The rooted growths of the previous season were easily traced to the mother plant, which was evidently little more than a 1-year-old seedling. In the case of older plants it was difficult to disentangle the rhizome growths. This plant has purplish yellow flowers and glandular hairy pods. Its nature seems to fit it for growth in arid regions, especially in sandy soils or in those not liable to become hard. There is a possibility that this plant may be found to endure considerable cold, as the rhizomes are very deep in the soil.

WILD RHIZOME-FORMING ALFALFAS.

Mr. Frank N. Meyer has been very successful in securing seeds and plants of rare alfalfas, some of which show rhizome development far in excess of any of our cultivated forms, with the exception of *Medicago sativa gaetula.* These alfalfas include forms of *M. falcata* which, together with the forms secured by Prof. Hansen, show a variation in height from a few inches to 5 feet 8 inches. These plants vary widely in their underground characters, in that some from very cold regions have exceedingly long taproots which evidently do not branch until they are several feet in the ground. A plant of this nature obtained by Mr. Meyer in Siberia is seen in Plate II, figure 1. Another very hardy form does not produce a taproot, but has a branching type of root. This is S. P. I. No. 20721.[1] Plants of *M. falcata* found in the Caucasus and Crimean regions, which are said to be protected during the winter by a deep covering of snow, show absolutely no signs of taproots, but their long rhizomes are well developed and produce roots along their entire length. (Pl. XI, fig. 2.) Late in the fall the tips of these rhizomes come to the surface or near it. Those which have small leaves above the surface do not seem to suffer in the least when exposed without any covering to a temperature of —13° F.

All these plants have been used in crossing with diverse strains, such as the Grimms, Turkestans, and others. The dwarf *Medicago falcata* has been crossed with a taller growing rhizome-bearing form of the same species. The winter condition of this hybrid is seen in

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[1] The letters "S. P. I." stand for "Seed and Plant Introduction," and the numbers refer to the series of plants and seeds brought into the United States by the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry.

Plate III, figure 1. The rhizomes go down in the ground to a depth of over 12 inches. (Pl. III, fig. 2.)

There are exceedingly dissimilar types of *M. falcata*, all of which for want of descriptive specific and varietal names must be classed under a single name. The plant to which Linnæus gave the name *falcata* was a prostrate form, but to what extent it was prostrate will perhaps never be known, as herbarium specimens of prostrate forms might be easily mistaken for decumbent ones.

Between the two extremes in height mentioned, forms characterized by other differences are found, such as semiprostrate and decumbent forms, some with hairy pods perfectly straight, others sickle shaped, some with smooth pods, some black, others brown, and some of them even with glandular pubescence. In the foliage there are quite as many variations: broad, narrow, flabby, hard, dark green to bluish green, some with a great profusion of flowers, others with but few, and all of them shy seeders, possibly on account of a seemingly meager supply of pollen grains. The pods of most of them shatter badly, but Mr. Meyer has found a strain in Siberia which does not shatter.

NEW RHIZOME-FORMING ALFALFA HYBRIDS.

Among the numerous consignments consisting of several species and varieties of alfalfa received in recent years by the Office of Foreign Seed and Plant Introduction a few of the plants gave decided promise as parents of new strains for pasturage purposes.

These alfalfas have been under observation for three seasons. They are natives of the Crimea and the Caucasus. Their principal claim to attention is their ability to bury the resting buds of the rhizomes several inches under the soil, which not only insures a crop of branches for the following season by reason of considerable protection from low temperatures, but also prevents the destruction of the plants by browsing animals. Among the new plants there is considerable diversity in habit of growth. Some of them are quite prostrate, never attaining a height over 6 inches. Some of these, however, give a fairly large quantity of forage, but on account of their prostrate natures can not very well be converted into dry fodder. Some of the forms have bluish purple flowers and very small, dark-colored, twisted pods. Other forms are between the last-named and the semi-upright forms of *Medicago falcata*. None of them is of strictly upright growth to such an extent that it could be harvested by ordinary methods. Even in their present condition, some of these prostrate forms are fairly well adapted to grazing purposes and in this capacity they would probably excel all other low-growing legumes. However, there are some which are quite prostrate and which do not have rooting rhizomes and some which are without rhizomes of any description.

During the summer of 1910 the best of these prostrate plants, which were well provided with deeply set rhizomes, were crossed with forms of *Medicago falcata*, which also showed good rhizome development but almost prostrate growth above ground. These hybrid strains are being developed for the several areas where ordinary alfalfa does not succeed. Plate III, figure 1, gives a fair idea of their ability to withstand extremes of drought and cold. During the summer the plants were repeatedly cut over at a point 1 inch below the surface of the soil. When finally they were allowed to grow they made a more rampant growth than those plants which were left uncut. (Pl. IV, fig. 1.)

In order to obtain moderately large quantities of seeds quickly vegetative propagation will have to be resorted to. One man can place in sand enough cuttings in one day to plant a quarter of an acre in rows 3 feet apart, the plants 18 inches apart in the rows. The cuttings are easily manipulated. It is only necessary to cut them with a sharp knife, each cutting to be 3 to 5 inches long, according to the variety and the condition of growth, remove the lower leaves, and set in sand. When kept cool, moist, and protected from sunshine they root within three weeks. They are then placed in flats of soil; within 10 days strong roots are formed. (Pl. V, fig. 1.) After a rain they are transferred to permanent quarters in the field. The plants will, in a measure, take care of themselves. If any large overshadowing weeds make their appearance they should be cut down until the young alfalfa plants have ripened a crop of seed. Plate III, figure 1, shows a plant from an 8-inch pot. The cutting from which this plant grew was rooted in May, 1911, and the photograph was taken in October of the same year.

These new rhizome-forming alfalfas will probably succeed best in the Northwestern and Eastern States having limestone soils. They do not succeed so well in heavy soils as they do in soils having a considerable proportion of sand. There is also a possibility that some of the hybrid forms will thrive in the semiarid regions of the country.

DEVELOPMENT OF ROOTING RHIZOMES OF PASTURAGE ALFALFA HYBRIDS.

It is exceedingly interesting to watch the development of the rooting rhizomes on the artificial hybrids. Sometimes rhizomes develop on the seedlings when only a few weeks old. A good example is a young plant of cross No. 284 (see Pl. X, fig. 2), which has as its parents Grimm. F. C. I.[1] ♂ No. 138 ♀ × S. P. I. No. 28042. The latter is thought to be a form of *Medicago sativa gaetula.* A mature plant of this cross is seen in Plate VI. The seedling mentioned has the rhizomes attached to the root fully 3 inches below the bases of the lowest buds, which are situated immediately above the cotyledon scars. Cases of this nature must be somewhat rare, as they have been found by the writer only in this cross.

Other plants of this cross, examined eight months after they were planted out, show the point of attachment of the rhizomes to be the basal portions of the original branches from the axils of the cotyledons. These rhizomes begin their growth within two months after germination. (Pl. VII, fig. 1.) By the end of September several growths above ground were formed at a distance of 10 inches from the main crown, and from the bases of these growths a large crop of rhizomes are again formed before the advent of cold weather. (Pl. VI.) Many of the individuals of the crosses, especially those in which the Peruvian alfalfa has been crossed with a plant having very long underground rooting rhizomes, show a condition the significance of which can not be predicted with certainty. The growth above ground is strictly upright. The dormant rhizomes are much divided and very stout; in several instances they are from 3 to 6 inches below the soil surface. If these turn out to be of the rooting form, we shall have a desirable type of alfalfa very different from any now in cultivation.

RHIZOMES AND THEIR FUNCTIONS.

The rudiments, at least, of underground rhizomes have been found on all the very hardy species of alfalfa and their numerous forms found in a wild state.

Through hybridization these rhizomes in a modified form are more or less present in nearly all of the hardy and semihardy strains now growing in the United States and Canada. All the strains grown by the writer, including those bred from selected plants by Prof. Wheeler, of South Dakota, and also numerous selected plants of hardy Grimm alfalfas (Pl. VIII, fig. 1) and other varieties secured by Mr. Westgate, of the Bureau of Plant Industry, together with plants secured by the writer from many other sources, show modified rhizomes.

In the greater number of plants the bases from which these underground shoots are produced are several inches beneath the surface.

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[1] The letters "F. C. I." stand for "Forage-Crop Investigations," and the numbers refer to the series of plants and seeds used in the investigations of the Office of Forage-Crop Investigations of the Bureau of Plant Industry.

It has also been found that a number of plants produce roots from these modified rhizomes. This peculiarity is responsible for the so-called stooling of many plants in hardy strains. The function of the rhizome and its modifications is undoubtedly to produce a large quantity of growth above ground and to protect the lower winter buds, which are situated well below the surface of the soil, thus providing for the perpetuation of the plant under conditions that are unfavorable for the taller growing forms. In the case of Grimm, F. C. I. No. 138 (Pl. VIII, fig. 1), which has true rhizomes, their function is twofold—that of protecting the buds from extreme cold by burying them several inches beneath the surface and of increasing quickly the area of the crown. Some plants of the Grimm variety which had true rhizomes have been found with crowns 2 feet in diameter. One of the principal functions of the large rhizome development of those varieties recently found in northern Africa may be the storage of water in their underground shoots to tide them over the very hot and dry summers, because the rhizomes of these plants in northern Africa are evidently formed at the close of the growing season, which is during the winter months, but when brought to a colder climate they form during the autumn months. The rhizomes are also instrumental in leaving a large amount of humus in the soil.

In some of the pronounced rhizome-bearing alfalfas taproots are not well developed, but it has invariably been noticed that those with poorly developed or small taproots have a very large number of rhizomes, which when fully developed send down roots of their own to a considerable depth the first season while still attached to the parent plant. Where this occurs the growing end of the rhizome develops branches above the surface. In favorable soil a single plant will cover several square feet of space in one season. Within this period a rooting rhizome has been observed to send down roots to a depth of 30 inches. The growth above ground on this rhizome is frequently as large as that of the original crown during the first season. (Pl. VI.)

DIFFERENT KINDS OF RHIZOMES.

Asa Gray defines the term "rhizome" as "A rootstock: A stem of rootlike appearance, prostrate on or under the ground, from which rootlets are sent off; the apex progressively sending up herbaceous stems or flowering stalks, and often leaves." The appearance of the rhizomes of the alfalfa during the first stages is, in all the forms noticed, of the same character; that is, they are of rapid development. The internodes are in most cases comparatively short, each one marked at regular intervals by rudiments of leaves and very large stem-clasping stipular growths. (Pl. II, fig. 2.) When the growing points of these rhizomes approach the surface the stipular growths assume a reddish color and the leaves gradually assume the usual shape. Those rhizomes which are produced on plants, such as the Grimm and Turkestan, often branch out laterally before reaching the surface, but they seldom produce roots. However, they invariably start from the bases of the lower growths of the previous season. At each internode on the rhizome there is a dormant bud closely covered by the lower part of the stipular growth. These enable the plant, after occasional set-backs from unpropitious weather, to branch out from points well under ground. On other plants, such as those commonly found in northern Africa, the rhizomes will frequently travel 3½ feet by the middle of June before coming to the surface, and during their growth underground branching takes place to a greater extent than has been noticed on any other wild alfalfas; but the roots on these alfalfas are not well developed, at least they were not strongly rooted when examined about the middle of July. How they fare later in the season has not been ascertained, but the growths above ground at the period mentioned were not strong. The ground was exceedingly dry, and this would preclude the possibility of rank growth. The growth of this plant as seen under the intense heat and drought of African summers would be a most welcome sight in the semiarid parts of the United States. In some places this plant seemed to revel in what appeared to be almost pure sand.

ALFALFAS HAVING DEEP-SET CROWNS.

The deep-set crowns of alfalfas have been mentioned in several publications. A plant having this peculiarity attracted the attention of Thomas Le Blanc in England in the last half of the eighteenth century[1] and was found by him to be hardier than plants of *Medicago sativa*. Thus we have a very old record in which hybrid alfalfas with underground shoots were regarded as being hardier than ordinary *M. sativa*.

Brand and Waldron[2] found that at Dickinson, N. Dak., and at Stockton, Kans., the Mongolian alfalfa under very severe tests proved to be the hardiest of any of the newly imported strains, and in both places the crowns were more deeply set in the soil than other varieties. These authors say: "It seems likely that this adaptation, if it may be called an adaptation, is of importance in giving the tenderest part of the plant needed protection."

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[1] Miller, Philip. Gardener's and Botanist's Dictionary, 1807.

[2] Brand, C. J., and Waldron, L. R. Cold Resistance of Alfalfa and Some Factors Influencing It. Bulletin 185, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1910, p. 68.

Olin[1] mentions a plant of the Grimm alfalfa and one descended from a plant known as South Dakota No. 167, which showed stooling qualities, but he does not mention this peculiarity as correlated with hardiness. The Grimm alfalfa plant, however, is stated to have had 10 per cent more stems than any other unit plant under study in the nursery.

Some of the wild alfalfas belonging to the rooting-rhizome section are very distinct from the bunching varieties, such as the Peruvian and allied forms, and also from those on the rhizomes of which no roots are formed. On examining a well-developed rhizome-forming plant for the first time one is apt to have but a vague idea of its nature, and it is sometimes probably regarded as a freak. This is not to be wondered at, since no well-defined allusions to rhizomes have been found in treatises on the alfalfas, and yet we meet with fairly numerous instances of rooting rhizomes among the strictly prostrate forms of *Medicago falcata*, once in the Grimm, and always in the forms of *M. sativa gaetula*, and to a limited extent in *M. sativa tunetana* and in one or two others which do not seem to have been described hitherto.

NONROOTING RHIZOMES.

At least three of the prostrate-growing alfalfas from the Caucasus region produce rhizomatic growths underground. During the two summers since planting, these rhizomatic growths have not produced roots. Like the plants which have rooting rhizomes, the underground growth is made during the autumn months from the bases of the previous summer's shoots. Some of the shoots are only about 3 inches in length and from that to 15 inches. Their growing points appear through the soil surface in early spring and in a short period thereafter a dense carpet of green is produced. This arrangement of the rhizomes is evidently a provision for their protection from severe frosts, as they are found growing at an elevation of 5,000 feet. The immature shoots are thus protected from pasturing animals. The rhizomatic growths in these alfalfas are invariably white in color and not much over one-sixteenth of an inch in diameter.

Numerous semirhizome-producing forms of *falcata-sativa* hybrids behave in a slightly different manner, but on the same general plan as these last mentioned, in that the young shoots for the following season's growth bury their growing points in the soil during autumn and remain buried during winter. In some plants they are not more than 1 inch in length and in others from 2 to 6 inches. Those forms which approach the latter size are usually branched (Pl. IX, fig. 1); the color of the rhizomes is purplish red, more pronounced on the stipular parts than on the stems. On the approach of favorable weather the growing points of the rhizomes are inclined toward the surface. Under the influence of light they change from purplish red to dull green, leaves following rapidly on the change of color. A peculiar feature of the rhizomes of this class is found in the very large stipules which sometimes cover a goodly section of the rhizome and which are developed to several times the size of the ordinary stipules (Pl. II, fig. 2). This arrangement of underground growth gives effective protection during winter and abundant space for the development of the shoots above ground.

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[1] Olin, W. H. Establishing a Breed of Alfalfa for the Irrigated Lands of Colorado. American Breeders Magazine, vol. 2, no. 4, 1911, p. 284.

The common forms of *Medicago sativa* when met with in a semiwild state are seldom of such luxuriant growth as they are under good cultivation. As a consequence, the individual shoots are well developed and the bases are smaller and not crowded. It therefore seems that the plant which develops its growth by means of underground rhizomes, each pointing away from the crown, has the best chance of a long, healthy career in the field. So far as the development of the growth and the consequent longevity of the plant are concerned, it will also be likely to withstand severe winters much better than bunching forms, because the resting buds or partly developed rhizomes are usually protected by the bases of the old growths and commonly by from 1 to 3 inches of soil. It frequently happens in alfalfas having short nonrooting rhizomes that roots will be formed on the prostrate but ripened branches near the crown, as seen in Plate X, figure 1.

DIFFERENT SEASONS OF GROWTH FOR ABOVEGROUND AND UNDERGROUND STEMS.

The alfalfas of the *sativa* section, which includes the *sativa-falcata* hybrids with the rhizome-forming *falcata* characters predominating, seem to make but little growth above ground after the close of summer, except during wet spells, when the season for growth above ground is slightly prolonged. When, however, the underground growth begins, which it does during the fall, differing in the time of starting with the different varieties, the upper portion of the plant seems to make no progress whatever. All the energies of the plant are directed to the development of underground shoots, which from this period until the beginning of cold weather make very rapid growth.

VEGETATIVE PROPAGATION OF SELECTED PLANTS.

It is important that an individual alfalfa plant which is an artificial hybrid or one which has been selected from old strains and which has been bred to come true from seed should be raised quickly in large quantities. Raising seedlings from the original plant gives only a limited number of plants the second season and so on till we find that several years elapse before there is enough seed to sow an acre of ground. In the same period that it takes to raise enough seed to sow an acre it is possible to raise a crop of seed from plants propagated from cuttings that will sow from 10 to 20 times that area. This is accomplished by asexual propagation, not by the division of the roots but by cuttings made from the growing stems above ground. The use of the seed method alone for several generations of increase from a single plant should be abandoned, not only because it is too slow, but because of the danger to which the plants are subjected each year through cross-pollination. Brand[1] unwittingly confuses two very distinct methods of vegetative propagation of individual alfalfa plants—that of propagation by cuttings of the shoots (Pl. VIII, fig. 2) and that of propagation by division of the crowns. It is possible within a year to raise plants from cuttings from a single individual of certain strains to cover more than a quarter of an acre of ground. On the other hand, by dividing a stooling plant—that is, cutting it into pieces—each piece having buds and roots attached, not over 50 plants at the most will be the outcome in the same space of time, and in the bunching plants only a very small number will result.

The method of vegetative propagation worked out by the writer a few years ago has been somewhat improved. When it is desired to grow a large number of plants from a single individual, so that a considerable quantity of seed may be obtained in a reasonably short period, this method may be used to advantage. The cuttings should be made as long as possible, so that several of the buds in the axils of the leaves will be under the ground. This obviously implies that in the rhizome-forming alfalfas branches will be produced from underground buds, thus building up a plant with the lower part of the crown buried in the soil. Cuttings for this purpose are made from 4 to 5 inches in length, all the leaves being removed except three or four at the growing end. The cuttings are quick to root when placed in clean sand. Cold frames and sash are necessary to keep the cuttings from wilting during the rooting process. After rooting they are hardened off, gradually removing the sash. The rooted cuttings can then be placed in a convenient receptacle and planted out in rows which are prepared beforehand. They may be planted with a dibble in much the same way that cabbage seedlings are planted.

ALFALFA CROSSES.

Many crosses were made during the summers of 1909 and 1910, principally to obtain an abundance of new forms so constituted as to thrive in areas where the common alfalfa does not succeed, and possibly to shed some light on the parentage of certain strains now growing in different parts of the country. Of some of those which were crossed in 1910 many of the seeds germinated too late in the summer of 1911 to give flowers. However, several plants of each cross flowered and fruited sufficiently to show the nature of the hybrid progeny.

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[1] Brand, C. J. Peruvian Alfalfa: A New Long-Season Variety for the Southwest. Bulletin 118, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1907, p. 27.

A few of the principal features of the parents and hybrid plants are given in the necessarily brief descriptions of the individuals of each first-generation cross. It should be borne in mind that the descriptions of the individual plants cover only the first summer's growth above ground and also the autumn period when the underground shoots are formed.

It is a very easy matter to raise a hybrid alfalfa, but if it is raised according to the easy way it is worse than useless. The common bumblebee in five minutes will do the work necessary to raise a dozen hybrids, but these hybrids will be trouble mongers. As a rule, only one of the parents is known, which is not sufficient.

To prosecute the work of crossing alfalfas faithfully entails much tedious preliminary work, especially that part which is absolutely necessary, the selection of pure parents. This in itself necessitates self-pollination of their flowers to ascertain whether their progeny comes true to the type selected. If this is not attended to, the operator will often get a hybrid, or at least a seedling likely to be mistaken for a hybrid, which is merely a plant in which expression is given to recessive characters in the parent plants.

THE DEVELOPMENT OF FIRST-GENERATION SEEDLINGS.

The hybrid progeny resulting from mating two plants each of which has been bred to reproduce true to its own pollen can be depended upon to be intermediate between the parents selected.

This hybrid progeny of the first generation must be self-pollinated and the seeds sown. The seedlings will consist of a large number of varying forms, giving as large a variation as we get in second-generation crosses of the cowpea. All of the varying forms should be subjected to a test for hardiness, which will probably result in a considerable proportion being victims of low temperatures. Individual selections should then be made from the plants which come closest to the ideals of the experimenter. From 10 to 20 plants will be sufficient. The flowers on each plant are again to be self-pollinated and about 100 plants raised from the seeds of each individual. There will be comparatively little variation in the progeny from each second-generation plant in this generation, and the most that can be done is to select those individuals that are similar in every way to the selected plants of the second generation, discarding the others. The next generation of plants raised from seeds resulting from self-pollinated flowers will give plants that as a rule can be depended upon to come true from seeds, provided that pollen from other strains is excluded. This is the great difficulty to overcome, and its solution is not an easy one. Isolation from other strains is the only practicable way of solving the difficulty. Just how far they should be grown from other strains to preclude the possibility of insects carrying undesirable pollen to the flowers has not yet been determined.

The method of raising new alfalfas was up to a few years ago solely through the agency of insect visitations. It was the only one available and, unfortunately, it is still used, though not to the same extent as formerly. The bumblebee is not discriminating. It may or it may not bring the desired kind of pollen to the stigmas of the flowers of the proposed seed plant, and seeds gathered from them will probably result in many dissimilar plants, to the bewilderment of the experimenters.

THE TEST OF THE METHOD OF PREPARING FLOWERS FOR CROSSING.

The successful depollination of alfalfa flowers and those of other plants of this family previous to applying foreign pollen to the stigmas may be ascertained by a very easy method and will show the beginner whether the work has been done well or otherwise. It is a test which should be tried by everyone engaged in this line of work.

Select 100 flowers and depollinate by a jet of water, as explained in a recent bulletin of the Bureau of Plant Industry.[1] Allow the stigma to assume its natural position on the banner of the flower, but without the application of pollen to the stigmas. If no seed is produced, then it may be assumed that the depollination was thorough in each case. In the application of water to the stigmas different periods of time may be given four series of 25 flowers each, training the jet of water on the first 25 flowers for a period of 5 seconds, on the next 10 seconds, and on the third and fourth series 15 and 20 seconds, respectively; label each series and note the results, which will serve as a guide for thorough depollination.

THE SOWING OF THE HYBRID SEED.

As a result of crossing the flowers of any two plants it very frequently happens that but a small number of seeds is secured. In order to get as high a percentage in germination as possible, it is necessary to provide the best conditions, so that every seed will have an opportunity to sprout. This part of the work is just as important and requires as much skill as the actual work of crossing. With alfalfa seed sown shortly after ripening the best results have been obtained with pure sand, covering to a depth of five-eighths of an inch. The receptacles for the soil should be 6-inch flowerpots. If sown in flats, the seeds should be 1½ inches apart in the row and the rows the same distance apart. The reason for wide spacing is that the seeds do not all germinate at the same time; there may be a difference of two to three months between the appearance of the first and last seedlings of a few seeds secured from cross-pollinated flowers. Therefore, the wide spacing gives an opportunity to remove and pot a seedling which appears quickly, without displacing the other seeds. The space from which a seedling has been removed should be marked with a toothpick and the vacant spaces in a partly seeded row should be similarly indicated. It has happened that seeds will lie in the soil for many months without germinating, even under favorable conditions so far as temperature and moisture are concerned. These seeds should be carefully taken up, rubbed gently between two pieces of sandpaper, and resown in pure sand. They will, as a rule, germinate in a day or two, and as soon as the cotyledons reach full size they may be pricked off around the edge of a 6-inch flowerpot.

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[1] Oliver, G. W. New Methods of Plant Breeding. Bulletin 167, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1910.

PLANTS WITH A POOR POLLEN SUPPLY.

There is abundant evidence to show that the anthers of the flowers of some *Medicago falcata* plants are in many cases either devoid of pollen grains or at most have a very limited supply. The variety of *M. falcata* known as S. P. I. No. 20721 is an example of the latter condition. Insects visiting flowers of *M. falcata* seem to be seldom successful in effecting pollination, as very few flowers on any one plant set seed. During the summers of 1910 and 1911 a large plant of the above serial number did not produce a single pod; it was isolated from other alfalfas, but insects had access to it at all times. It would seem from the correspondence of the Bureau of Plant Industry with observers in the *M. falcata* regions that most forms of this species are more or less shy seeders. There are forms of *M. falcata*, however, which are abundant seed producers and, strange to say, they seem to have pods of the nonshattering form.

THE DEVELOPMENT OF SEEDLING ALFALFAS.

The manner of the development of growth from the cotyledon stage in spring to the end of the first season or the beginning of cold weather is exceedingly interesting, especially when studied in connection with those hybrids which produce rooting rhizomes.

It is somewhat remarkable to find that the rhizome-forming growth of most plants has its origin in the axils of the seed leaves. Plate VII, figure 2, shows this gradual growth from a seedling in the cotyledon stage to the development of a plant 6 weeks old. Plate VII, figure 2, *A* and *B*, shows a seedling with the cotyledons and one with the first foliage leaf. The subsequent growth of the first shoot above the seed leaves is only a few inches, because its function is to keep at work just long enough to enable the buds on the lower part of the shoot to develop. The seedling at *D* (Pl. VII, fig. 2) shows a bud perfected in the axil of one of the cotyledons before their decay. This seldom happens, because the seed leaves immediately before this stage are little more than breathing surface and keep the plantlet alive, so that the roots and true leaves will be able to take care of themselves. The first lateral growth is usually seen sprouting from the axil of the leaf, with a single blade. Another shoot develops in the axil of the leaf immediately above it. These two shoots make considerable growth, depending upon the variety or species. In this case it is the intention to show merely the beginning of the rhizomatic growth, which develops fully when the seedlings are less than a year old. Plate VII, figure 2, *E*, shows the beginning of the development of the rhizome. These two growths are from the axils of the cotyledons, being formed before their decay. At this stage they necessarily are in a very immature state. Plate VII, figure 1, shows their condition several weeks later. They are then quite large and easily distinguished from the growths above.

It would seem that the main root contracts considerably, or at least sufficiently to enable the part originally occupied by the cotyledons to be drawn below the surface of the soil, because some simple experiments conducted with the object of ascertaining why the neck of the plant is sometimes deep in the soil suggested no other explanation than the contractile nature of the roots.

Out of many thousands of seedlings examined only a single instance has been found where zhizomes were developed below the part originally occupied by the seed leaves. This very remarkable growth occurred in one of the seedlings of cross No. 284, Plate X, figure 2, which shows two rhizomes developing fully 3 inches below the point occupied by the cotyledons. However, when seedling crosses where one of the parents has rhizomes are carefully planted out with the portions occupied by the seed leaves exactly level with the surrounding soil it has almost invariably happened that within six months those parts of the stems formerly occupied by the cotyledons are from 2 to 3 inches below their former levels, while some allowance must be made for the firming of the soil due to beating rains and to other causes.

Those plants which are drawn down into the soil are commonly of the rhizome-producing types. The rhizomes may be anywhere from 3 or 4 inches to 3½ feet in length.

The alfalfa plants which are drawn down into the soil form a considerable proportion of the individuals of the Grimm, Turkestan, Baltic, and Mongolian varieties. These conclusions are drawn from many hundreds of seedlings from hardy strains sent to the writer by Prof. W. A. Wheeler, of Mitchell, S. Dak.

DESCRIPTIONS OF CROSSES.

CROSS NO. 191 (MEDICAGO FALCATA, S. P. I. NO. 20721 ♀ × M. SATIVA, S. P. I. NO. 17698 ♂).

The seed-bearing parent, *Medicago falcata* (S. P. I. No. 20721), is one of the tallest of this species. It has been grown on the Department grounds for three seasons. During the first summer it attained a height of 2½ feet, the second season 3½ feet, and during the summer of 1911 it reached a height of 4½ feet. It is a semi-upright plant and belongs to that section of *M. falcata* the plants of which are almost or entirely without rhizomes. The large dormant buds, however, are under the surface of the soil. Late in the season it produces a dense crop of very short growths not over 3 inches in length. The stems of these shoots are not thicker than a pin and the leaves are very small. If this is a normal growth, it would seem to function in the protection of the crown during winter. The root of this plant is the largest of any seen by the writer. In digging to ascertain the depth to which it descends, the task had to be abandoned, because at 8 feet below the surface the roots were still quite large. They probably descend to a depth of over 20 feet.

The pollen-bearing parent is a hardy form of *Medicago sativa* (S. P. I. No. 17698) from Chinook, Mont. It is a bushy upright plant, but it is evidently not a typical *M. sativa*, because seedlings raised from inbred seed showed unmistakable characters indicating that it has a small percentage of *M. falcata* blood in it.

Cross No. 191 is one of the few crosses of which the first-generation plants were invariably alike. From a close scrutiny of the 16 plants raised it was impossible to detect any variation. This is owing to the fact that both parents do not vary from inbred seed, as subsequently proved. Before the flowering period, the 16 plants looked as if they might have been typical *M. sativa;* in fact, it was thought that a mistake had been made. However, when the first flowers opened, this supposition was dispelled. The flower colors of the plants were invariably alike and they resembled the color of the foliage to such an extent that the plants had to be examined closely to find all the flowers. Before and during the flowering period the first-generation plants were kept in a large wire cage to prevent the flowers being cross-pollinated by insects. The flowers were then tripped by hand and a generous supply of seeds secured.

The second-generation plants were raised during the winter of 1910–11. The progeny of each of the plants of the first generation were kept separate. In this generation the colors of the flowers varied exactly as was expected, ranging from the color of *Medicago falcata* to that of the *M. sativa* parent. The plants of both generations resemble the pollen parent to a much greater degree than the seed parent in so far as habit and foliage are concerned. The general appearance of the flowers and fruit of the parent plants and also those of the first-generation cross is shown in Plate XI, figure 1.

Owing to the numerous progeny of the second generation, the flowers could not be given the same careful treatment to insure self-pollination which was accorded to those of the first generation. However, they were grown in a cool greenhouse and carefully tripped by hand.

The pods of the second generation vary from about two-thirds of a turn to about two turns.

A very noticeable feature in over two-thirds of the progeny of the second generation is the disposition of the plants to form short underground nonrooting rhizomes in autumn immediately after the cessation of top growth. In some of the plants this character is much more accentuated than in others. The plant of *Medicago sativa* from Montana (S. P. I. No. 17698) does not show this character to such a degree as do the hybrid progeny and in the *falcata* parent it is observable only to a very slight degree. It is nevertheless fortunate that the larger number of the second-generation plants have this character, as it obviously means better equipment for northern latitudes. These underground growths are all from the bases of the shoots of the previous summer. They make a horizontal growth of 2 to 3 inches and remain under ground during winter ready to branch out at the surface on the approach of spring. These underground branches even when their tips are within less than half an inch of the surface of the soil do not seem to be injured during cold weather. Some of the plants in large pots have been exposed all winter without any covering and escaped injury although the temperature fell to −13° F. on one or two occasions. With the branches 3 inches below the surface, under good field conditions they will probably stand the lowest possible temperatures of the Northern States. The pollen-bearing *M. sativa* parent from Montana did not have underground growths, but the plant was grown in a large pot in firm soil. Consequently it did not get an opportunity to develop as it would have done had it been planted in the field. The seed-bearing parent is only fairly well supplied with underground buds, but those examined showed they were not true rhizomes. Perhaps the short rhizomes in the hybrid progeny are due to a latent character in one of the parents. The growth of every one of both the first and second generation plants does not in the least resemble that of the *M. falcata* parent in the development above ground either in the leaf blades or stipules, but the flower color in the first generation is uniformly intermediate between the colors of the flowers of the two parents, and in the second-generation plants the colors range from that of the seed parent through the intermediate shades to that of the pollen parent.

This and other crosses show that if we take an inbred plant of one of the standard varieties of *Medicago sativa* and cross it with all of the many different forms of *M. falcata*, including those with straight and falcate pods, smooth and hairy, upright, decumbent, and prostrate in habit, we will get the basic forms of practically all of the varieties comprising the very numerous and divergent forms common at the present time, which undoubtedly descended from hybrids and which now pass as mere forms of *M. sativa.*

While many crosses raised from the various forms of *Medicago falcata* and *M. sativa* are more or less decumbent, some of the plants of cross No. 191 are upright and very different from the plants of crosses in which other forms of *M. falcata* take a part. From this we must come to the conclusion that the characters of the various forms of *M. falcata* should be carefully studied before the plants are used when upright-growing progeny are wanted. According to the experience gained during the last few years, a dwarf straggling form of *M. falcata* used either as the male or female in a cross will not produce upright progeny, but a plant of *M. falcata* having an almost upright habit, when crossed with an upright *M. sativa*, will give progeny a little less erect than *M. sativa*, but much more erect than the *M. falcata* parent.

CROSS NO. 284 (GRIMM, F. C. I. NO. 138 ♀ × S. P. I. NO. 28042 ♂).

The pollen-bearing parent of this cross is S. P. I. No. 28042, a large-leaved prostrate plant thought to be *Medicago sativa gaetula*, from the Caucasus Mountains at an altitude of about 4,000 feet. This plant has long rooting rhizomes. The seed parent is a Grimm alfalfa, F. C. I. No. 138 (Pl. VIII, fig. 1), which is possibly one of the few plants of this partly hardy strain which has short rooting rhizomes. It represents what is probably the hardiest of this strain and was selected for breeding, not so much because it was a Grimm alfalfa, but because it was one of the first plants noticed by the writer to have the resting buds several inches beneath the surface of the soil. This Grimm alfalfa plant has undoubtedly descended from an old strain which originally had the rhizome character much more developed and probably was originally a cross between a *M. sativa* and a semiprostrate rhizome-producing form of *M. falcata.* However, the Grimm alfalfa (F. C. I. No. 138) is possibly a seedling from a very old plant and perhaps one of the original plants resulting from the seed sown in Minnesota which is said to have been brought from Germany in 1857.[1] There seems to be some doubt as to the identity of the pollen-bearing parent, as a description of it does not exactly agree with that of any published species or variety. It seems an intermediate form between *Medicago glandulosa* and *Medicago sativa gaetula.* The flowers are light purple with the exception of the keel, which appears to be light yellow while the flower remains untripped, probably owing to the partly transparent nature of the keel, allowing the color of the stamens to be seen. The pods are much larger than those of *M. sativa* and are densely studded with glandular hairs. The plant is only about 6 inches in height, and during the summer a seedling plant will cover about 4 square feet. The rhizomes are abundant, pure white, and produced in October and the first part of November at Washington, D. C. They push their way to the surface in April, and after leaves are formed they produce roots. The shorter rhizomes come to the surface near the crown, the longer ones appearing farther from the center of the seed-bearing plant.

The plants of the first generation which have flowered, 44 in number, are all hybrids, shown by the fact that the pods have glandular-haired pubescence, resembling in this particular the pollen-bearing parent, while the pods of the parent Grimm alfalfa are smooth. The flower color of the hybrid plants resembles that of the pollen parent. The height of the stems of the tallest plants is about 24 inches, ranging from that to about 15 inches, but consideration must be given to the fact that the plants were set out from 4-inch pots about the middle of May and after ripening a comparatively small number of pods their energies seem to have been spent on the development of an enormous quantity of underground rhizomes. Plate X, figure 2, shows a seedling which began to form rhizomes when only a few weeks from the germinating stage. By the beginning of August some of these rhizomes had well-developed roots with considerable growth above ground. By the end of October the tremendous rhizome formation had ceased and the plant thus assumed its winter stage. (Pl. VI.)

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[1] Westgate, J. M. Variegated Alfalfa. Bulletin 169. Bureau of Plant Industry, U. S. Dept. of Agriculture, 1910, p. 21.

This plant far surpasses any other wild or cultivated plant so far observed by the writer in the production of rooting rhizomes. Many of these underground growths are from 2½ to 3 feet in length. The other plants of the same parentage, so far as the development of the underground rhizomes is concerned, have some rhizomes branching to a greater degree than the one mentioned, but they are not quite so long. There is every indication that these plants will cover a larger space than any of the others, either of hybrid origin or otherwise, and owing to the resting buds being very deep in the ground they will probably be very hardy. It is intended to try these and other individuals of the same cross over a wide range of territory as soon as practicable after they have been developed at Washington, D. C., to the third generation, which will take at least two years more to accomplish.

CROSS NO. 289 (GRIMM, F. C. I. NO. 131 ♀ × MEDICAGO SATIVA GAETULA, S. P. I. NO. 26590 ♂).

The Grimm alfalfa used as the seed bearer in this cross is quite unlike F. C. I. No. 138 in that it has no rooting rhizomes, but the plant is so deep in the soil that the shoots situated at the lower part of the crown are covered to a depth of from 2½ to 3 inches. It is thus protected during very low temperatures. It was selected by Mr. Westgate from a field of the Grimm alfalfa on Mr. Ensler's farm near Excelsior, Minn., and was chosen by the writer for crossing because of its deep crowns, upright growth, height, and leafiness. *Medicago sativa gaetula* (S. P. I. No. 26590), the pollen-bearing parent, is from Algeria. This plant is probably quite hardy, but of this we have no direct proof, as it seemingly has never been tried in excessively cold regions. It has a very vigorous lot of rhizomes, which are developed early in autumn. These rhizomes are deeply buried in the soil.

From the appearance of the plant in summer one would not imagine it to be a good hay-producing type. However, it promises to be a good plant to grow in light sandy soils in regions where the annual rainfall is light. From the hundreds of resting buds deep in the soil it would seem that it would be unaffected by drought or extreme cold. In the semiarid parts of the country it will probably grow better than any other alfalfa. This supposition is based entirely on its exceedingly long underground rhizomes deep in the ground. These very numerous rhizomes terminate in shoots above ground and eventually produce strong roots. Another good feature is the large number of resting buds at short intervals along the entire length of the rhizomes.

The pods of *Medicago sativa gaetula* are thickly studded with glandular hairs. The flower color is bluish purple tinged with yellow.

Plant No. 289–3.—Flowers greenish purple, yellow keels; glandular-haired fruit; foliage bluish green; crowns deep in the soil; short rooting rhizomes. These rhizomes were formed before the plant was 6 months old. Stems and leaves without hairs. Growth made during the first summer, about 18 inches in height.

Plant No. 289–4.—Flowers greenish purple; glandular-haired pods; erect habit. The numerous rhizomes were 8 inches long by the beginning of November. Rhizomes begin to send down roots in early spring. Leaves and stems slightly hairy. Growth made during the first summer, 19 inches in height.

Plant No. 289–5.—Flowers greenish purple, yellow keels; glandular-haired fruit; foliage bright green; leaves and stems smooth; rhizomes resembling those of the pollen parent in length, but stouter, sending down long roots; growth made during the first season, about 1 foot; scant vegetation above ground, evidently due to enormous rhizome development.

CROSS NO. 293 (GRIMM, F. C. I. NO. 131 ♀ × MEDICAGO FALCATA, S. P. I. NO. 24455 ♂).

The plants of this cross promise to be very cold resistant, as the seed bearer, Grimm alfalfa, was secured from seed gathered from a plant known to be hardy in North Dakota, the flowers of which were self-pollinated; nearly all of the seedlings resemble this plant, especially in their equipment to stand very cold weather.

The pollen-bearing parent is S. P. I. No. 24455, a form of *Medicago falcata* found by Prof. Hansen north of Semipalatinsk, western Siberia. It is stated that plants of this form were found with stems 5 feet 8 inches long.[1]

Plant No. 293–1.—The flowers of this plant are greenish purple; stems 20 inches tall; slightly decumbent; no underground rhizomes present, but there are numerous short shoots at the bases of the summer's growths. The crown is low down in the soil.

Plant No. 293–3.—Flowers greenish purple; crown deeply set in the soil; goodly supply of stout, short branching rhizomes, which in October point downward in the soil; stems and leaves smooth; height, 18 inches.

Plant No. 293–5.—Flowers greenish purple; very stout branching rhizomes. During summer the bases of the shoots produced numerous roots when the plants were 5 months old. Height of growth, 20 inches; stems and leaves smooth; promises to form very large crowns.

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[1] Willis, C., and Bopp, J. B. Progress in Variety Tests of Alfalfas. Bulletin 20, South Dakota Agricultural Experiment Station, Brookings, S. Dak.

CROSS NO. 294 (GRIMM, F. C. I. NO. 131 ♀ × S. P. I. NO. 28042, PLANT NO. 6 ♂).

The Grimm alfalfa seed bearer in this cross is the same as used in cross No. 293 The pollen-bearing plant was found in the Caucasus region at an elevation of 4,000 feet and is therefore assumed to be hardy. If the depth of the rooting rhizomes of wild plants is an indication of the hardiness of a plant, this ought to be an exceptionally hardy strain and probably also drought resistant.

Plant No. 294–1.—Flowers very light purple, with yellow keels. Fruits profusely covered with glandular pubescence; crowns deeply set in the soil; growth 18 inches tall; upright; no rhizomes; branches of crown rooting at a point from 1 to 2 inches above top of taproot.

Plant No. 294–2.—Flowers light purple, keel yellow; pods large, with glandular hairs; free seeding; no rhizomes; crown of plant low down in the soil.

Plant No. 294–3.—Flowers purple, keel yellow; glandular hairs on fruit; height of plant 18 inches; stems and leaves smooth; very heavy crop of rhizomes, all of them very stout and much branched; some of the most advanced in growth produced roots before the advent of cool weather.

Plant No. 294–4.—Flowers light purple, not changing in color; pods with glandular hairs; plant erect; height of growth the first season 18 inches; very thick branching rhizomes starting at a point 3 inches beneath surface of soil.

CROSS NO. 295 (GRIMM, F. C. I. NO. 131 ♀ × MEDICAGO FALCATA, S. P. I. NO. 24455 ♂).

For description of parents, see cross No. 293.

Plant No. 295–1.—Flowers almost yellow, faintly shaded with purple; very short rhizomes; crown deeply set in soil. The rhizomes begin from a point 4 inches below the surface. Height 20 inches. A promising plant.

Plant No. 295–3.—Flowers almost yellow, faintly purple on opening, changing to green with age; rhizomes very short, but forming roots and tops the first season; crown 8 inches in diameter when seven months from the seedling stage. A promising hardy form.

Plant No. 295–4.—Flowers yellow, faintly purple on opening, changing to purplish green; of upright growth; 20 inches in height during first season; leaves and stems smooth; crown deeply set in soil; strong rhizomes formed in October from a point 4 inches below surface of soil. A promising hardy form.

CROSS NO. 299 (PERUVIAN, G. AND G. NO. 60 ♀ × S. P. I. NO. 28042 ♂).

The seed-bearing parent of cross No. 299 is a typical Peruvian alfalfa from Yuma, Ariz. (Pl. V, fig. 2.) This variety is characterized by a strong upright growth and hairy stems and leaves. The crown of the plant is usually at or very near the surface of the soil. It is a comparatively tender strain, although it has withstood the cold of several mild winters at Washington, D. C. It has been shown to be capable of withstanding a lower temperature during the development of growth at Yuma, Ariz., than any other variety.[1] The very hairy stems and leaves in all probability have something to do with its ability to stand low temperatures when growing.

The pollen-bearing parent, S. P. I. No. 28042, is a dwarf-growing plant from the Caucasus region at an elevation of 4,000 feet. It has bicolored flowers. The banner and wings are light purple and the keel is yellowish. The pods are almost as large as the variety of *Medicago sativa* known as *tunetana*. The pods also resemble those of *M. sativa tunetana* in that they have glandular hairs.

Plant No. 299–1.—Flowers very light purple, yellowish keel; pods with glandular pubescence; height of growth during first season 24 inches; young stems purplish; leaves and stems hairy, plainly showing the blood of the Peruvian variety. The transmitted male characters are noticeable in the yellowish keel of the flower and the very thick and long rooting rhizomes. Growth upright, strong. The rhizomes averaged about 15 inches in length by the end of October, making a crown over 2 feet 6 inches in a single summer. This plant promises to form a very much larger crown in a short period. It will possibly be much hardier than the typical Peruvian variety. It seems peculiarly well suited for growing in warm areas where irrigation is lacking, but it remains to be seen just how this alfalfa will behave in the field, as the profusely developed underground rooting rhizomes are exceedingly robust. There is no doubt that the blending of these two plants will result in a strain to outward appearances somewhat like the Peruvian, but with thoroughly protected underground parts.

There are 26 other plants of this cross, the seeds of which germinated late in the season and which have not bloomed, but their characters so far indicate that they are more or less like plant No. 299–1.

CROSS NO. 300 (PERUVIAN, G. AND G. NO. 60 ♀ × MEDICAGO FALCATA, S. P. I. NO. 24455 ♂).

The seed bearer, No. 60, is a typical Peruvian from the original plants which withstood several winters at Washington, D. C. It is not provided with underground rhizomes and the resting buds are fully exposed during the winter. As it is a strictly upright and tall-growing form, it was selected for crossing with one of the very hardy forms of *Medicago falcata* (S. P. I. No. 24455, Pl. X, fig. 1) brought by Prof. Hansen from a district in Siberia where the mercury is said to freeze in the thermometers with no snow on the ground.[1] This form of *M. falcata* is comparatively low growing at Washington, D. C. It was planted alongside S. P. I. No. 20721. Its greatest height in two years amounted to only about 12 inches. The broad crown of the plant is deep in the soil, and numerous but very short growths are made in the autumn from the lowest buds. It was crossed on Peruvian to ascertain the result of a union between one of the tenderest and one of the hardiest of the alfalfas.

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[1] Brand, C. J. Peruvian Alfalfa: A New Long-Season Variety for the Southwest. Bulletin 118, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1907.

Plant No. 300–1.—Flower, greenish purple with slight traces of yellow; stems and leaves hairy. This plant has the crown exposed above the surface of the soil, showing the character of Peruvian alfalfa in this respect. No rhizomes; height 24 inches.

Plant No. 300–5.—Greenish yellow flowers; stipules not fringed at base. Although Peruvian alfalfa was the seed plant, there is no trace of it in the stems and leaves of this first-generation plant, it being absolutely without hairs, both on stems and leaves. This plant was put out too late to flower. It produces roots in abundance from the bases of the shoots during September. Seemingly a large-crowned form.

CROSS NO. 309 (S. P. I. NO. 28042 ♀ × F. C. I. NO. 131 ♂).

S. P. I. No. 28042 has already been described in former crosses.

Grimm, F. C. I. No. 131, was selected for its deep-rooting crown, the base of which was nearly 3 inches below the surface of the soil.

Plant No. 309–3.—The only plant which has flowered so far has light-purple and yellow flowers and glandular-haired pods. It is a semiprostrate form, very abundantly supplied with much-branched underground rooting rhizomes. (Pl. IX, fig. 2.) It promises well for intermountain areas. Out of the cross there are 13 plants which have not yet flowered. All of them have comparatively small round leaflets.

CROSS NO. 318 (GRIMM, F. C. I. NO. 269 ♀ × S. P. I. NO. 28042 ♂).

The Grimm parent of this cross is a second-generation seedling of F. C. I. No. 138, which has its resting buds deep in the soil. It was selected by the Office of Forage-Crop Investigations on account of extreme hardiness and number of stems. The pollen parent is S. P. I. No. 28042, which has been described in some of the foregoing crosses.

Plant No. 318–1.—Rose-purple flowers; pods with glandular hairs.

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[1] Hansen, N. E. The Wild Alfalfas and Clovers of Siberia, with a Perspective View of the Alfalfas of the World. Bulletin 150, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1909.

The crown of this plant is well protected by being from 2½ to 3 inches deep in the soil. Roots are developed from the bases of branches during the first season. (Pl. I, fig. 2.)

Plant No. 318–2.—Not yet flowered; rhizomes poorly developed; stems and leaves smooth; well protected by deep-rooted crowns.

Plant No. 318–3.—Light-purple flowers; pods with glandular hairs; strong rooting rhizomes; medium-good upright growth. The plant has a deeply seated crown.

Plant No. 318–4.—Greenish purple flowers; glandular-haired pods; long, creeping rhizomes well under the ground, the best plant of the cross in this respect. Plant upright in growth.

Plant No. 318–5.—Very light purple flowers; glandular-haired pods; stems almost smooth; dwarf, bushy; no rhizomes.

Plant No. 318–6.—Light-purple flowers; glandular-haired pods; a bushy, upright plant with a few short rhizomes.

Plant No. 318–8.—Flowers very light purple and yellow; glandular-haired pods; plant strictly upright, 18 inches tall, stems and leaves slightly hairy. This plant has the base of the crown at the surface.

CROSS NO. 320 (S. P. I. NO. 28042 ♀ × PERUVIAN, G. AND G. NO. 60 ♂).

This is very decidedly an instance in which some of the principal characters of the male parent preponderate over those of the female in the first-generation plants.

S. P. I. No. 28042, the seed bearer of the above cross, has glandular-haired pods and a more or less procumbent habit, with a generous supply of underground rooting rhizomes. The flowers are large, light purple in color except the keel, which has a yellowish cast. This plant was collected between Dushet and Passanaura, Caucasus, Russia, at an altitude of 4,000 feet. It bloomed in June, 1910. Pollen from No. 60, a Peruvian plant, was applied to the stigmas of the glandular-haired plant. During the first few months after the resulting seeds germinated the growth of the hybrid progeny so closely resembled the pollen parent that at first the writer thought that a mistake had been made and that the seedlings were of the typical Peruvian alfalfa. The appearance of the flowers, however, dispelled this belief, because they resembled the color of those of the female parent. As the fruit approached maturity they were found to be thickly studded with glandular hairs, which is another character of the seed-bearing parent.

As the resting period approached, the plants developed numerous and very strong underground rhizomes. Thus it will be seen that three of the important characters were transmitted by the seed bearer to the hybrid progeny, viz, the glandular hairs, flower color, and rhizome development, while the pollen-bearing parent[1] transmitted upright stems, which, together with the leaves, are quite hairy and have a remarkable likeness to the Peruvian alfalfa.

It will be interesting to ascertain to what extent the male has transmitted its hardy nature to the hybrid progeny, as the underground parts of the plants are evidently perfectly equipped to withstand winters of a much more searching nature than the conditions prevailing where the Peruvian alfalfa succeeds best.[2] Very large branching underground rhizomes have been formed low down below the crowns of some of the plants. Other plants have unbranched rhizomes. These rhizomes seem to function in insuring a liberal supply of shoots at the commencement of the growing season. However, it is yet too early to judge of their nature in this respect. There can be no doubt, however, that these plants will each cover a considerable area of ground in one or two seasons.

Plant No. 320–1.—Stems upright; 3 feet in height: color of flowers light lavender; glandular-haired pods; no rhizomes. The crowns are deeply situated in the soil.

Plant No. 320–3.—Stems and leaves hairy; very large rooting rhizomes; crowns 8 inches in diameter at end of first season; pods with glandular hairs.

CROSS NO. 321 (GRIMM, F. C. I. NO. 135 ♀ × S. P. I. NO. 28042 ♂).

The seed-bearing parent is a plant which has the crown deep in the soil. A 1-year-old plant develops a crown about 8 inches across. Some of the principal divisions of the crown develop fairly large roots. S. P. I. No. 28042 is a plant with very abundant rooting rhizomes and prostrate habit.

Plant No. 321–1.—The Grimm parent is not an inbred plant; consequently the hybrid progeny has no resemblance to it. Its appearance is more like that of a Turkestan variety. The pollen-bearing plant has transmitted its rhizome-forming character and large glandular-haired pods.

CROSS NO. 322 (GRIMM, F. C. I. NO. 135 ♀ × S. P. I. NO. 28041 ♂).

The Grimm is the same plant used as seed bearer in cross No. 321.

S. P. I. No. 28041 is a semiprostrate plant found in the Caucasus Mountains. The flowers are very dark blue and very small. The pods are smaller than those of *Medicago cancellata* and quite black in color. The plant is provided with a large number of long rooting rhizomes.

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[1] This plant is from a rooted cutting from the individual plant of the Peruvian alfalfa from which pollen was taken in raising the first alfalfa hybrid by the now generally adopted method described in Bulletin 167, Bureau of Plant Industry, U. S. Dept. of Agriculture, entitled "New Methods of Plant Breeding." 1910.

[2] Brand, C. J. Peruvian Alfalfa, a New Long-Season Variety for the Southwest. Bulletin 118, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1907.

Plant No. 322-2.—All of the plants in this cross germinated late and did not flower in 1911. All of them have growth very much resembling that of *Medicago lupulina* above ground. Rhizomes fairly well developed under ground.

CROSS NO. 323 (S. P. I. NO. 25733 ♀ × S. P. I. NO. 28041 ♂).

S. P. I. No. 25733, the seed-bearing parent, is a form of *Medicago sativa* from Bridgeport, Kans.

S. P. I. No. 28041 is the same plant used as the pollen bearer in Cross No. 322.

Plant No. 323-1.—Flowers purple; glandular hairy pods; plant procumbent in habit; short rhizomes; crown deeply seated.

Plant No. 323-2.—Flowers purple; glandular hairy pods; leaves and stems smooth; growth straggling; supplied with a large number of short rooting rhizomes; height 18 inches; crown deeply seated.

Plant No. 323-3.—Flowers bluish purple; stems and leaves smooth; crown deeply set in soil.

Plant No. 323-4.—Not in flower; crown 2 inches below the surface; stems and leaves resembling those of Peruvian alfalfa; height of growth first season, 2 feet.

CROSS NO. 336 (S. P. I. NO. 26667 ♀ × S. P. I. NO. 26865 ♂).

The seed bearer, S. P. I. No. 26667, is a dwarf form of *Medicago falcata* from the Crimea, with straight smooth pods and light-yellow flowers. It is provided with a fair number of rhizomes near the surface of the ground. (Pl. IV, fig. 2.) The pollen-bearing parent, S. P. I. No. 26865, is from the Caucasus region and is a taller growing form of *M. falcata*, with straight hairy pods. The growth above ground is somewhat sparse, owing to the specimen received being small, but the new rhizomes are very abundant. The cross was made to ascertain whether a hybrid could be secured which could be used as a reliable pasture plant; that is, an alfalfa with short, dense growth and an abundant supply of underground rooting rhizomes. Some of the progeny are exceedingly promising. (Pl. III, fig. 1.)

Plants Nos. 336-1-32.—About 5 inches in height. The leaves are short and smooth, very close together on the stems, and bluish green in color. Most of the rhizome-forming alfalfas produce the principal crop of rhizomes in the autumn or late summer. This plant seems to stop growing only when the ground is frozen hard. It is also the first alfalfa to begin growing, as it is quite green in March. It produces rhizomes throughout the growing season. It looks exceedingly promising as a pasture plant because when shorn of all the stems and foliage above ground and down to a depth of 1 inch beneath the surface it soon recuperates and throws up numerous growths in a few days. The rhizomes are different from those of any other alfalfa noticed by the writer in that they send out roots along their entire length (Pl. III, fig. 2). Some of them have measured 3 feet in length. Rhizomes formed from the seedlings planted out in the summer of 1910 were found in the autumn of 1911 to have pierced the soil to a depth of over 12 inches. Plate III, figure 2, shows two pieces of rhizomes found at this distance below the surface. New rhizomes are seen sprouting from the old ones, proving that dormant buds deep in the soil are ever ready to send up new rhizomes to the surface. Each rhizome develops several branches. This is the easiest alfalfa to propagate vegetatively of all those with which we have experimented.

Several hundred cuttings were rooted in August, 1910. These were put in 5-inch pots and placed in an open frame. In numerous instances during the winter, mice had eaten the crowns of the plants, but this does not seem to have harmed the rhizomes in the least, as they were advanced to such a stage that roots were formed, and in the following summer a single plant in enriched rotten-granite soil covered a space of about 9 square feet. The growth during the first season is comparatively sparse, but dense enough to give abundant grazing material.

This hybrid does not take kindly to heavy clay-loam soils. It evidently prefers a soil which the rhizomes can pierce easily.

The rhizomes of this prostrate alfalfa are very different from those of all other species and forms in that roots are not produced at irregular intervals. On the contrary, as seen in Plate III, figure 2, at every internode numerous small roots are formed, some of which become fairly large the first season, especially after the foliage is produced. When the first growth is fairly well matured, other rhizomes form at a point between 2 to 3 inches from the surface, gradually but surely widening the area of growth. Plate V, figure 1, shows two cuttings only a few weeks old developing rhizomes.

CROSS NO. 389 (S. P. I. NO. 24455 ♀ × S. P. I. NO. 17698 ♂).

The seed bearer, S. P. I. No. 24455, is one of the very hardy forms of *Medicago falcata* procured by Prof. Hansen during his last trip to Siberia. Although it has been planted out for nearly three years alongside S. P. I. No. 20721, unlike the last named it does not grow to be over 12 inches high. It looks to be very hardy, however, judging from the numerous short underground rhizomes.

The pollen-bearing parent, S. P. I. No. 17698, is a plant of *M. sativa* from Chinook, Mont.

Plant No. 389-2.—The hybrid is upright growing with rather thin, wiry smooth stems, which with the rather small leaves would almost be taken for a plant of the Grimm alfalfa. It has not produced flowers thus far. The first-generation plants are very different from those of cross No. 191, which is between S. P. I. No. 20721 and the plant which is the pollen parent of the above cross. The plant is well protected during winter by very numerous short rhizomes, which are placed several inches under ground. The plants of this cross were all late in germinating. It is a promising combination for areas with very severe winters.

SUMMARY.

Among the large number of distinct forms of alfalfa collected mainly through the Office of Foreign Seed and Plant Introduction, some of the plants have revealed underground rhizome-forming characters which seem to be correlated with drought and cold resistance.

Modifications of these characters have been found in some of the cultivated strains, such as the Grimm, Baltic, Turkestan, and Mongolian alfalfas.

In the more tender alfalfas, such as the Peruvian, these characters seem to be absent.

Many crosses have been made between recently discovered rhizome-forming alfalfas and some of the standard varieties, not so much to improve the strains of alfalfa now growing in the alfalfa regions of the United States as to provide pasturage forms which will grow in areas not now suited to the needs of the standard varieties.

PLATES.

DESCRIPTION OF PLATES.

Plate I. Fig. 1.—A plant of *Medicago sativa gaetula* from northern Africa. In this plant the rhizomes are well developed, the branch at the left being more than 3 feet 6 inches long. The plant is about 2 years old and was found growing in soil composed largely of decomposed rock. This variety may be found to be valuable in the intermountain areas. Fig. 2.—A plant of cross No. 318. Seedling of Grimm, F. C. I. No. 131 ♀ × S. P. I. No. 28042 ♂. The pollen parent is from the Caucasus Mountains at an elevation of 4,000 feet. The seed parent was selected from a field of Grimm alfalfa on Mr. Ensler's farm near Excelsior, Minn., by Mr. J. M. Westgate, of the Bureau of Plant Industry. The seedling Grimm does not have rhizomes, but the male parent is well supplied with rooting rhizomes. In the hybrid the rhizomes are well under the surface of the soil.

Plate II. Fig. 1.—A plant of *Medicago falcata*, showing a taproot over 5 feet in length, diminishing in diameter very slightly when more than 5 feet below the surface. This plant has pods of the nonshattering form, which makes it valuable for future breeding. Fig. 2.—Nonrooting rhizomes of *M. sativa turkestanica*, showing the gradual development of leaves.

Plate III. Fig. 1.—A plant showing rhizomatic growth of cross No. 336 (S. P. I. No. 26667 ♀ × S. P. I. No. 26865 ♂), winter condition. All of the rhizomatic growth was developed before the end of October. This cross promises well as a pasture alfalfa. Fig. 2.—Rhizomes of alfalfa cross No. 336 (S. P. I. No. 26667 ♀ × S. P. I. No. 26865 ♂). Rooting rhizomes nearly 2 years old sending out new rhizomes. The dormant buds on the old rhizomes are plainly seen. These rooting rhizomes and resting buds were found 12 inches under the surface of the soil.

Plate IV. Fig. 1.—A plant of cross No. 336, showing recovery from a severe test which involved cutting the growth 1 inch below the surface of the soil six times during the summer. Fig. 2.—A plant of *Medicago falcata* (S. P. I. No. 26667) from the Crimea; seed-bearing parent of cross No. 336. This plant grows a little over 6 inches high and makes a very dense growth. It may be drought resistant.

Plate V. Fig. 1.—Rooted cuttings of pasture alfalfa cross No. 336 seven weeks after removal from propagating bed, showing rhizome development. The cuttings rooted in eight days after being placed in sand. Their condition a few months later is seen in Plate III, figure 1. Fig. 2.—A seedling Peruvian alfalfa plant, showing dormant buds unprotected. The crown is above the surface of the soil. This strain is one in which no rhizome-forming influence is apparent. The rhizome-forming alfalfas continue growing long after the Peruvian variety has become dormant at Washington, D. C., but while the growth is generally very abundant it is hidden from view. This fact may explain why the Peruvian alfalfa, which has no underground shoots, has a lower zero point of growth above ground than other alfalfas.

Plate VI. Plant No. 7 of cross No. 284 (Grimm alfalfa, F. C. I. No. 138 ♀ × S. P. I. No. 28042 ♂.) This plant is seven months from the seed. Some of the rhizomes are more than 3 feet long. One of the oldest rhizomes has developed branches and roots.

PLATE VII. Fig. 1.—A seedling of *Medicago sativa gaetula*, showing the beginning of rhizome growth. The lower buds are 1 inch below the surface of the soil. Fig. 2.—Seedling stages of a rhizome-forming alfalfa (*M. sativa gaetula*). *A*, Seedling with cotyledons developed. *B*, In the second stage the second leaf has only one blade; the next is trifoliate. *C*, Six leaves are seen on the first shoot, the stipules are plainly noticeable, and bacterial tubercles are seen on the root. *D*, The first shoot is nearing its maximum size and is becoming decumbent. The second shoot is starting from the base of the simple leaf. A bud in the axil of the cotyledon at the left may be plainly seen. *E*, Seedlings before attaining this size usually lose their seed leaves. The primary shoot has completed its growth, the secondary shoot from the axil of the simple leaf has made rapid progress, and the buds in the axils of the cotyledons have made considerable progress. The future rhizomes develop from the leaves of these two shoots.

PLATE VIII. Fig. 1.—Inbred seedling of Grimm alfalfa, F. C. I. No. 138. The seed-bearing parent of this plant withstood the winters of Minnesota since the introduction of the Grimm in 1857. The lower part of the crown is well beneath the surface of the soil. The short rooting rhizomes penetrate the soil to a depth of several inches. The crown of this plant spreads rapidly. Fig. 2.—Rooted cuttings of rhizome-forming and nonrhizome-forming alfalfas, three months from the cutting stage. *A*, *Medicago sativa gaetula; B*, Grimm, F. C. I. No. 131. At the lower part of the stem of *M. sativa gaetula* a rhizome has formed three branches, two of which have produced growth above ground. The third branch has descended into the soil. In the Grimm plant no rhizomes have formed and all the growth is above ground.

PLATE IX. Fig. 1.—A 6-months-old plant of Baltic alfalfa (No. C–25 Wheeler). Probably one of the parents of this plant was well supplied with rooting rhizomes. The rhizomes are well under the surface of the soil, and roots will evidently be produced the following season, making a very broad crown in course of time. Fig. 2.—A plant of cross No. 309 (*Medicago sativa gaetula*, S. P. I. No. 28042 ♀ × Grimm, F. C. I. No. 131 ♂). In early autumn the cessation of growth is quite sudden, but for several weeks later the underground rhizomes continue to develop.

PLATE X. Fig. 1.—A plant of *Medicago falcata* (S. P. I. No. 24455) 18 months from seed, one of the hardiest alfalfas. During the first season considerable stooling takes place. During the second season, as the crown enlarges, numerous strong anchor roots are developed, precluding any possibility of heaving. Fig. 2.—One of the original seedlings of cross No. 284 two months after germination. This seedling has developed two rhizomes fully 3 inches below the cotyledon scars and in itself tells the story of the hardy alfalfa, because even in this early stage the dormant buds have 3 inches of soil protection during the winter months.

PLATE XI. Fig. 1.—Flowers and pods of cross No. 191 (*Medicago falcata*, S. P. I. No. 20721 ♀ × *M. sativa*, S. P. I. No. 17698 ♂). Enlarged two diameters. The first flower and pod are from *M. falcata* (S. P. I. No. 20721). The flower and pod in the middle of the illustration are *M. sativa* (S. P. I. No. 17698). The hybrid (first generation) is seen in the flower and pod to the right. Fig. 2.—A plant of *M. sativa* (S. P. I. No. 28152), a wild rhizome-forming form from the Caucasus region.

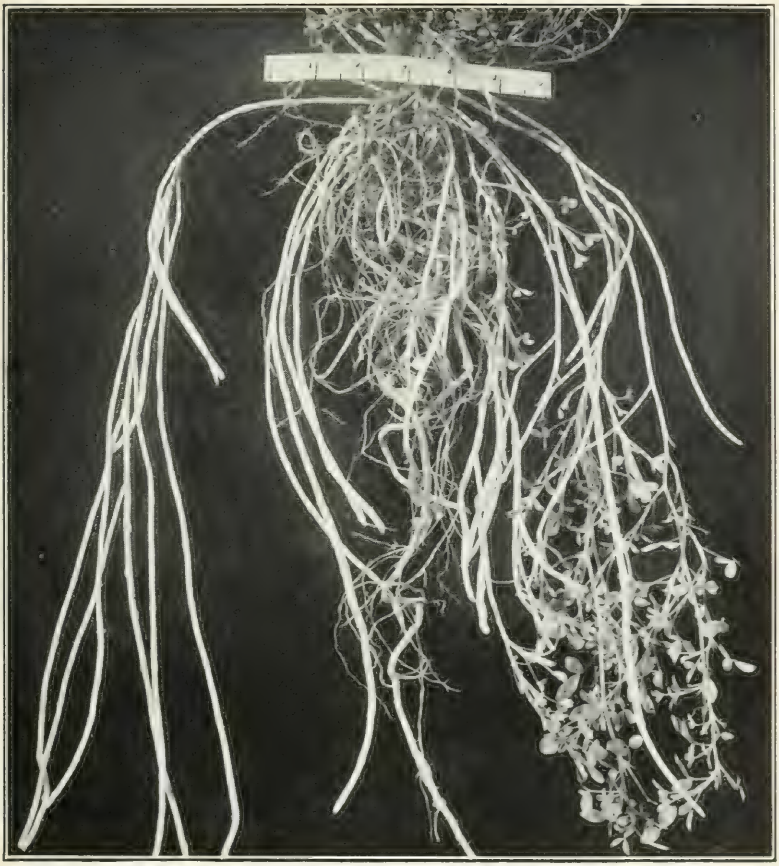


FIG. 1.—A PLANT OF MEDICAGO SATIVA GAETULA, SHOWING RHIZOMES 3 FEET 6 INCHES IN LENGTH.

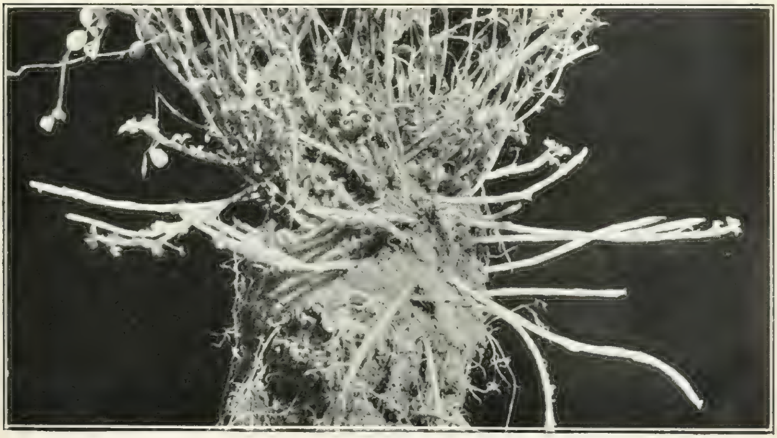


FIG. 2.—A PLANT OF CROSS NO. 318 6 MONTHS FROM THE SEEDLING STAGE.

Grimm, F. C. I. No. 131 ♀ × S. P. I. No. 28042 ♂.

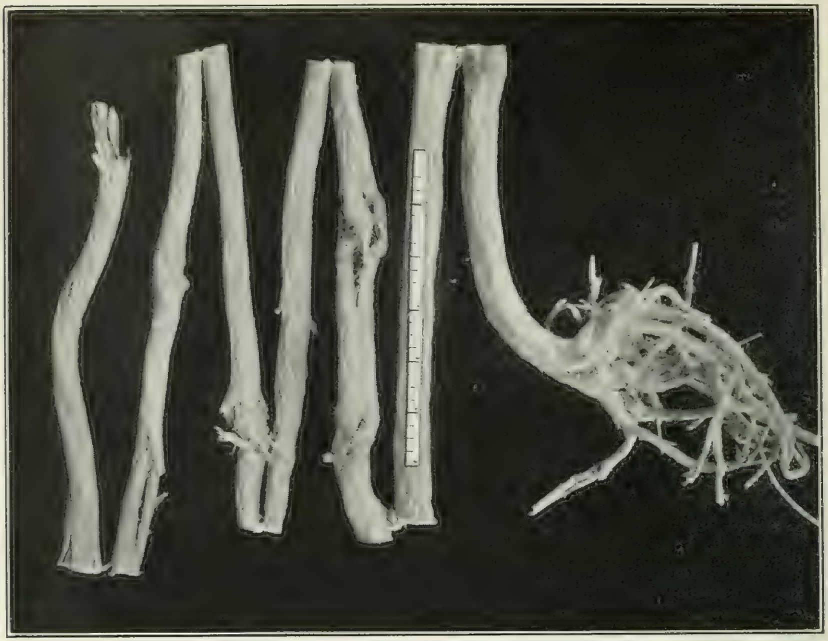


FIG. 1.—A PLANT OF MEDICAGO FALCATA, SHOWING A TAPROOT OVER 5 FEET IN LENGTH, DIMINISHING BUT SLIGHTLY IN DIAMETER.

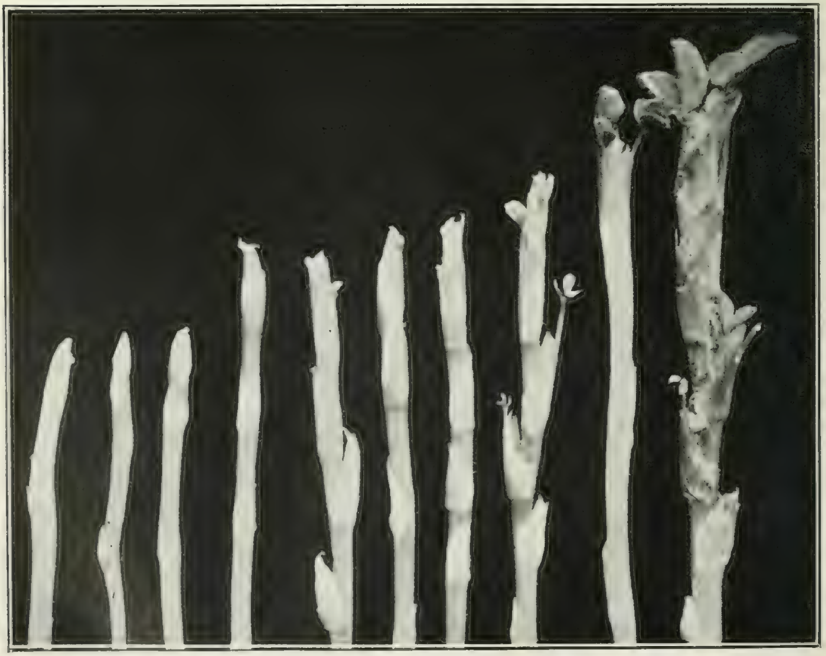


FIG. 2.—NONROOTING RHIZOMES OF MEDICAGO SATIVA TURKESTANICA, SHOWING THE DEVELOPMENT OF LEAVES.

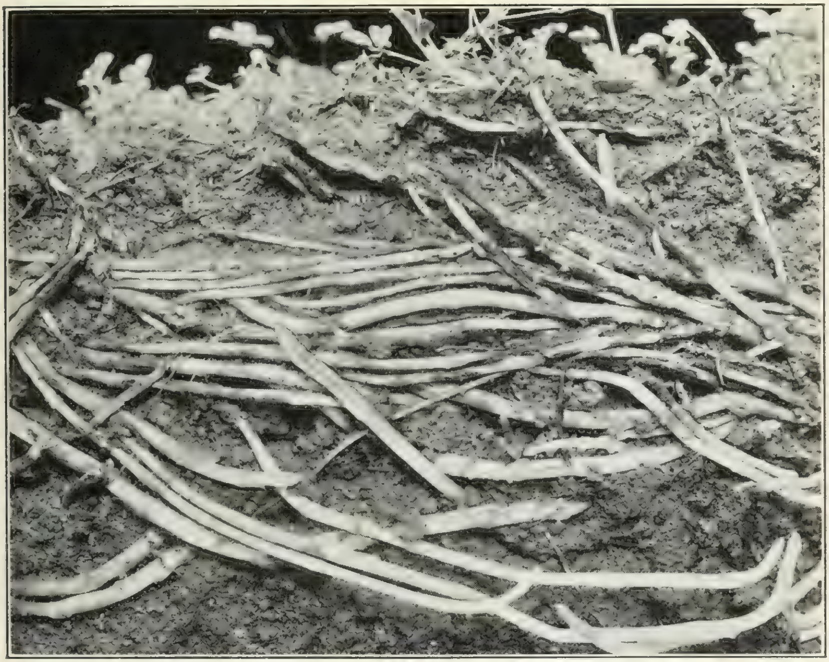


FIG. 1.—A PLANT SHOWING THE RHIZOME GROWTH OF CROSS NO. 336, WINTER CONDITION.

S. P. I. No. 26667 ♀ × S. P. I. No. 26865 ♂.

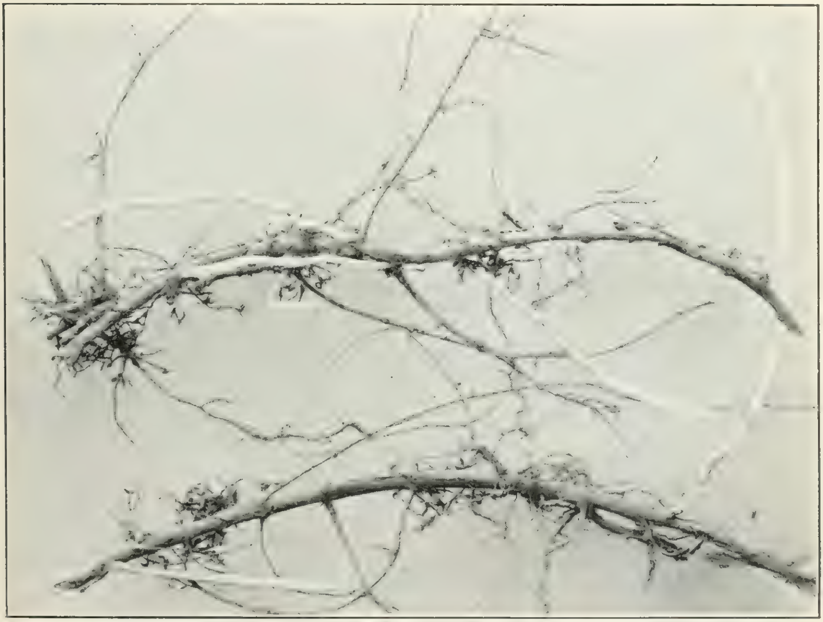


FIG. 2.—RHIZOMES OF ALFALFA CROSS NO. 336, WITH RESTING BUDS 12 INCHES BELOW THE SURFACE OF THE SOIL.

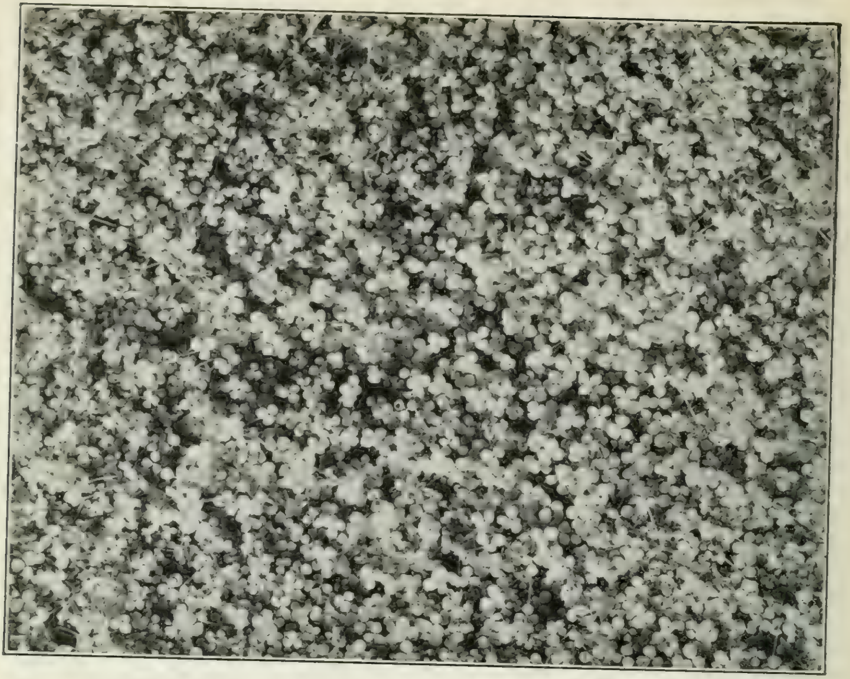


FIG 1.—A PLANT OF CROSS NO. 336, SHOWING RECOVERY AFTER A SEVERE CUTTING TEST.

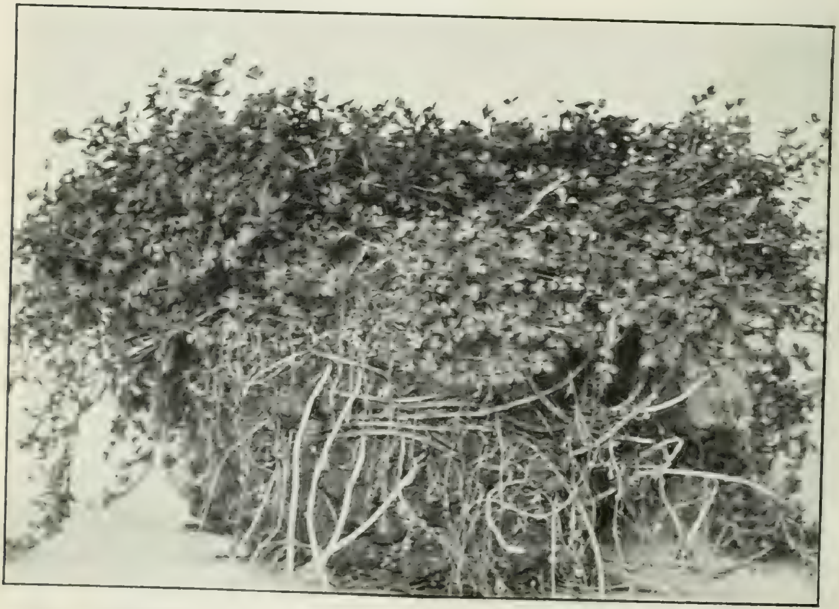


FIG. 2.—A PLANT OF MEDICAGO FALCATA (S. P. I. NO. 26667), THE SEED-BEARING PARENT OF CROSS NO. 336.

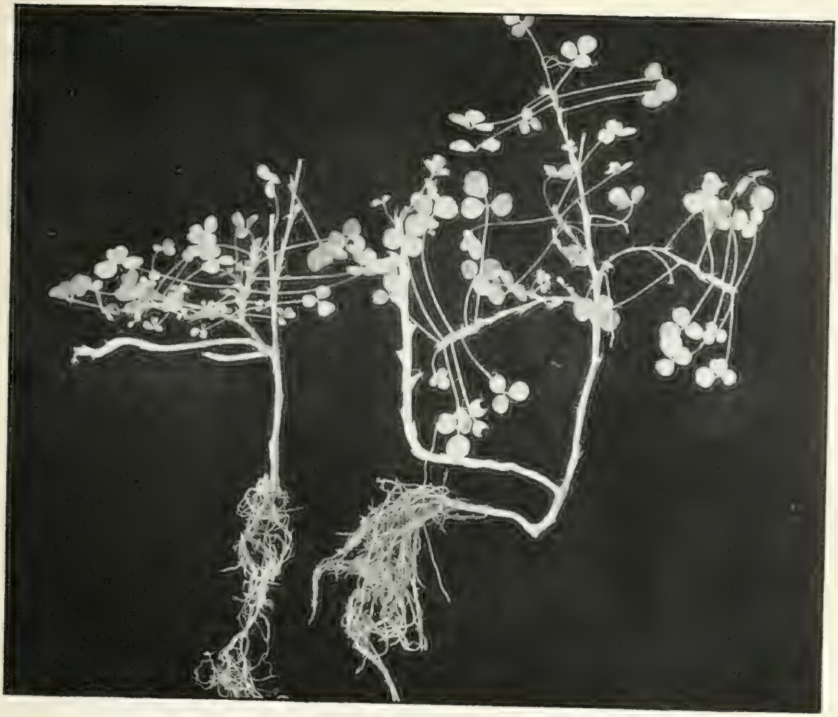


FIG. 1.—ROOTED CUTTINGS OF CROSS NO. 336, SHOWING THE BEGINNING OF RHIZOME GROWTH.

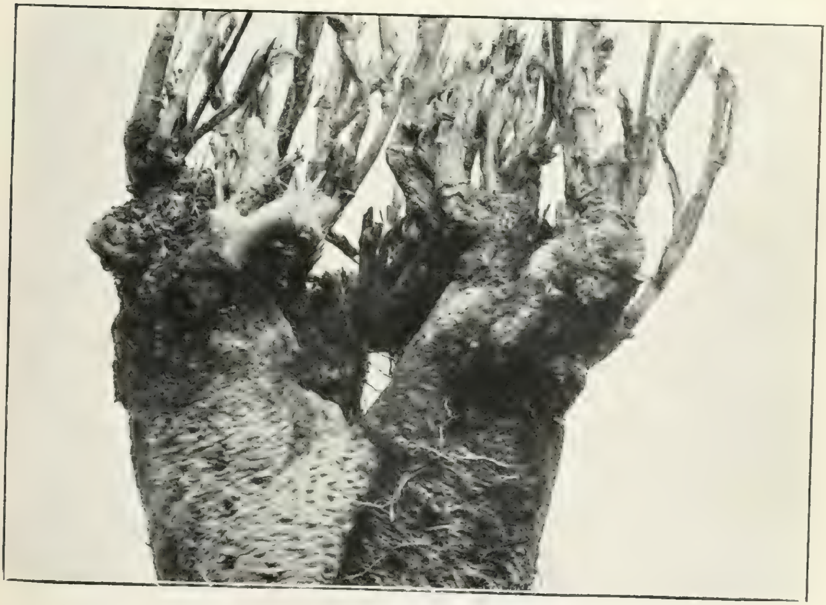
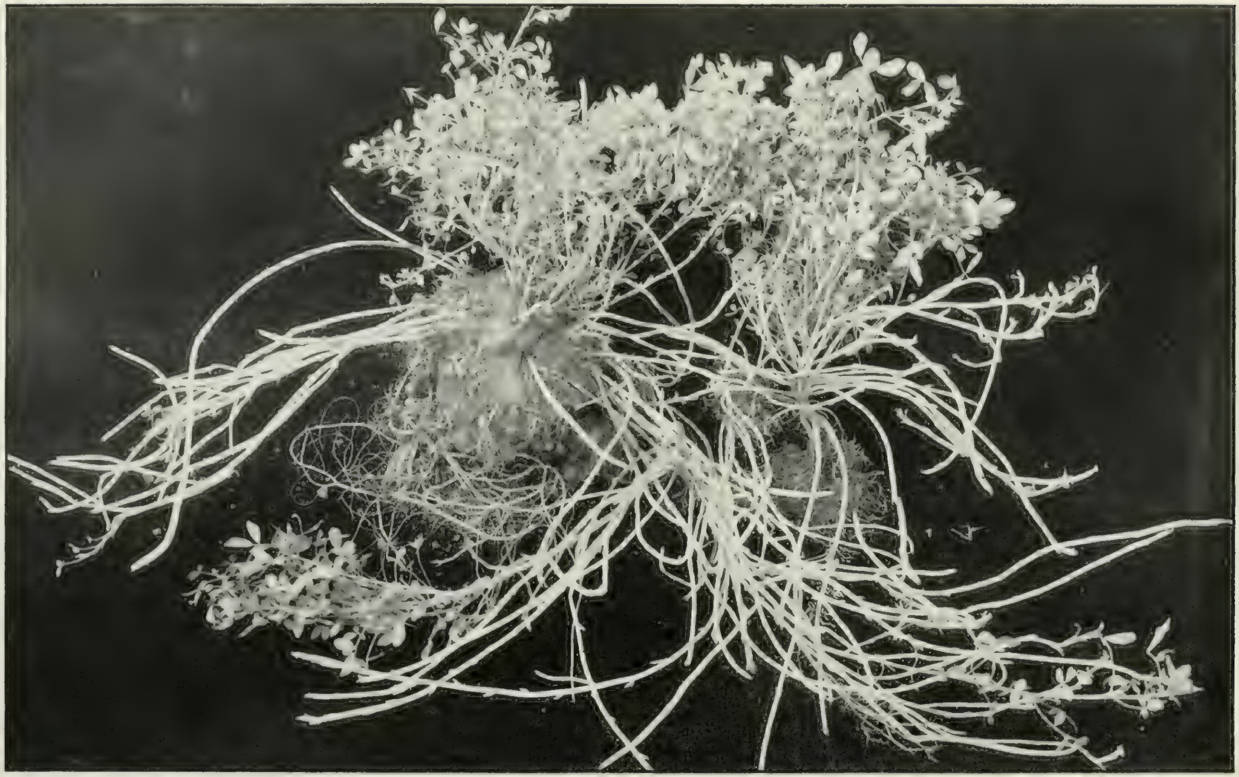


FIG. 2.—A SEEDLING PERUVIAN ALFALFA PLANT, SHOWING DORMANT BUDS UNPROTECTED.



PLANT NO. 7 OF CROSS NO. 284.

Grimm alfalfa, F. C. I. No. 138 ♀ × S. P. I. No. 28042 ♂.

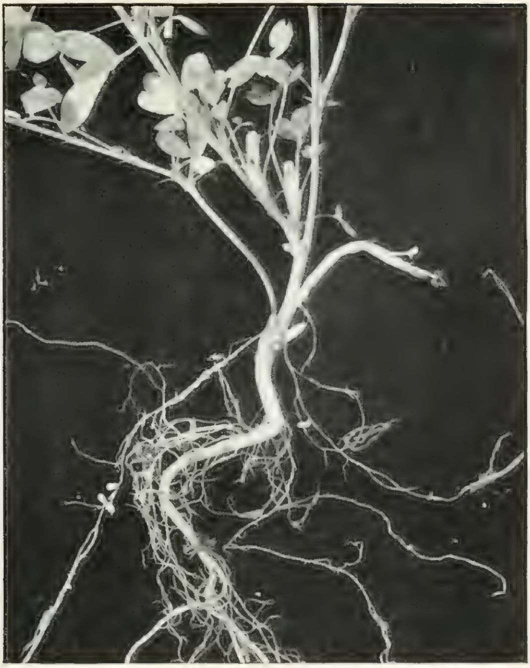


FIG. 1.—A SEEDLING OF MEDICAGO SATIVA GAETULA, 7 WEEKS OLD, SHOWING THE BEGINNING OF RHIZOME GROWTH.

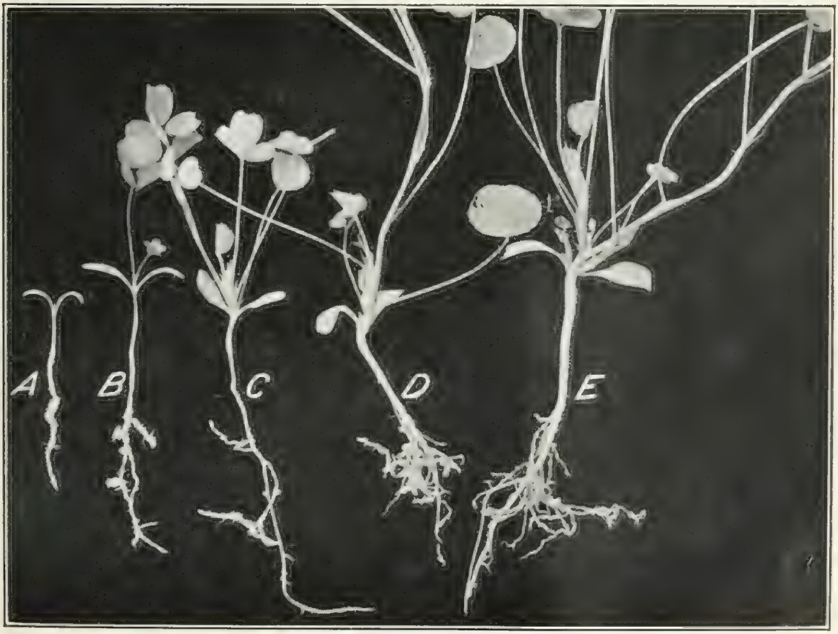


FIG. 2.—SEEDLING STAGES OF A RHIZOME-FORMING ALFALFA.

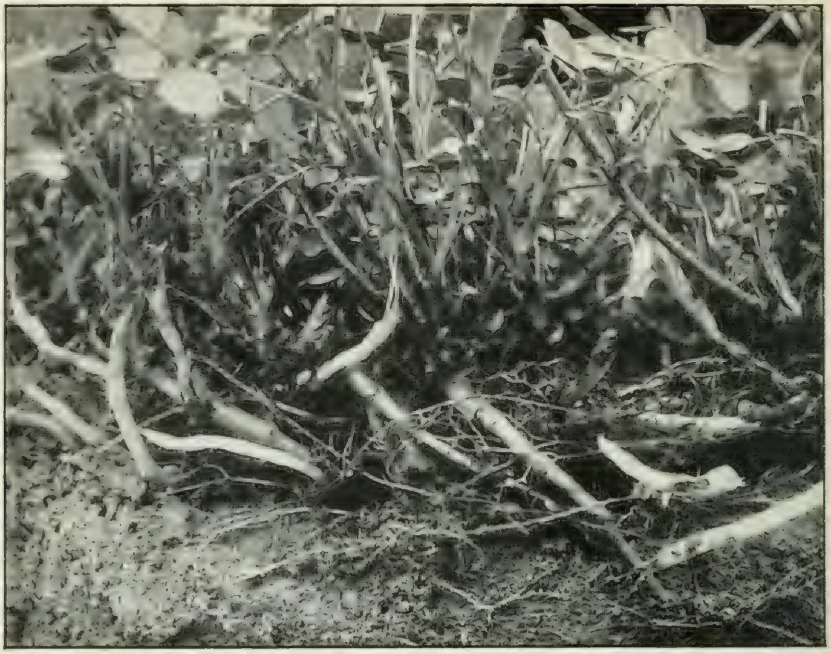


FIG. 1.—A PLANT OF GRIMM ALFALFA (F. C. I. NO. 138), ONE OF THE HARDIEST OF THIS STRAIN.

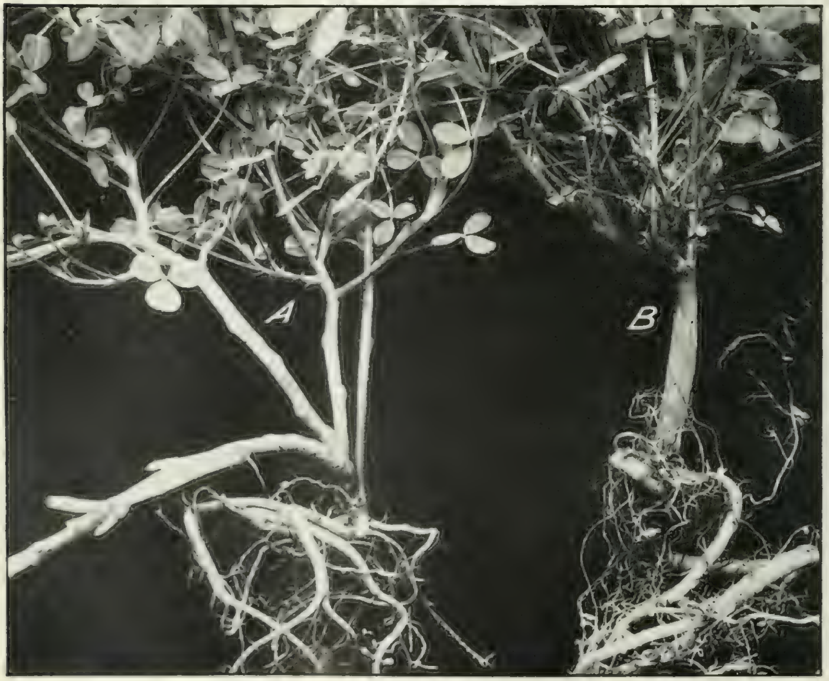


FIG. 2. *A*, A ROOTED CUTTING OF RHIZOME-FORMING ALFALFA. *B*, A ROOTED CUTTING OF ALFALFA NOT FORMING RHIZOMES.

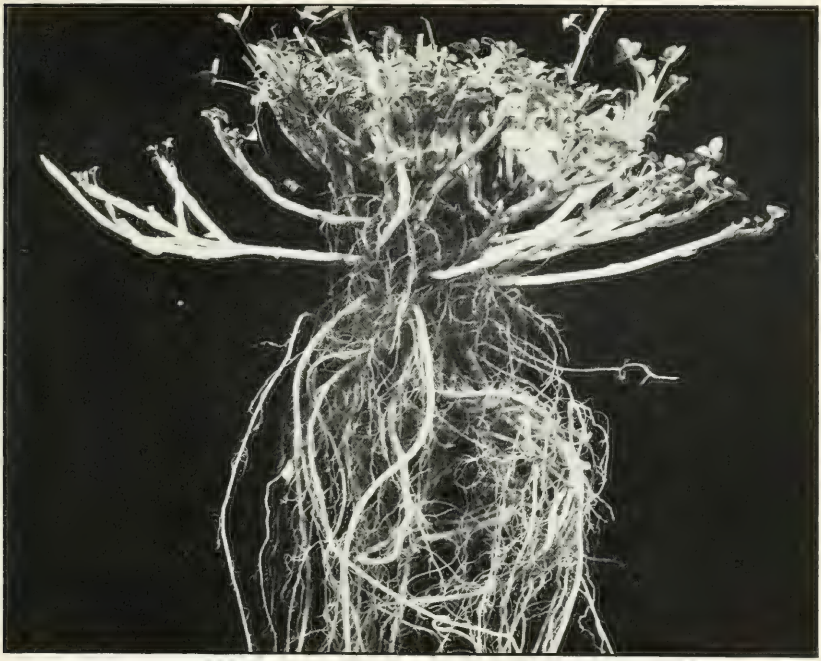


FIG. 1.—A PLANT OF BALTIC ALFALFA (NO. C-25, W. A. WHEELER), AN IDEAL TYPE FOR VERY COLD REGIONS.

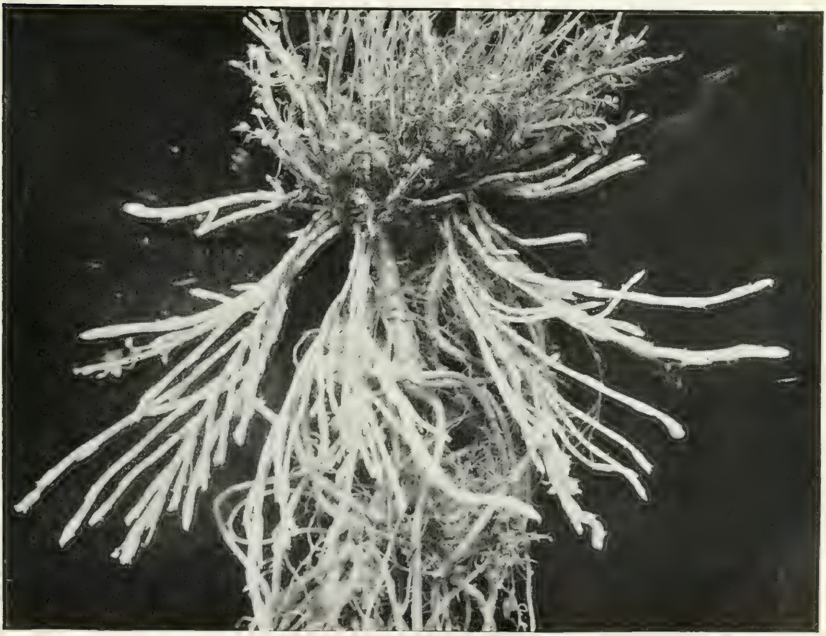


FIG. 2.—A PLANT OF CROSS NO. 309, WINTER CONDITION.

Medicago sativa gaetula, S. P. I. No. 28042 ♀ × Grimm, F. C. I. No. 130 ♂.

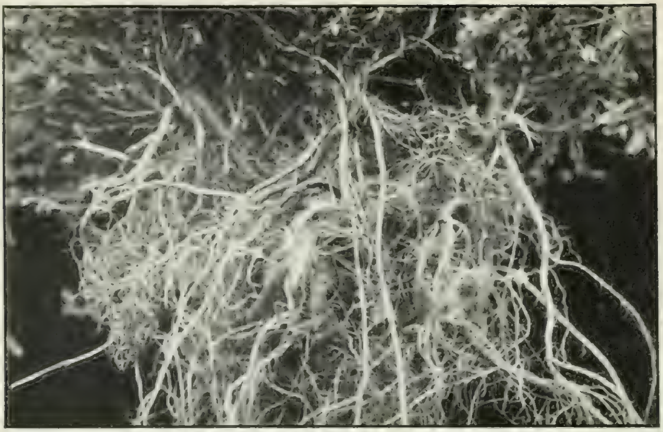


FIG. 1.—A PLANT OF MEDICAGO FALCATA (S. P. I. NO. 24455) 18 MONTHS FROM SEED; ONE OF THE HARDIEST ALFALFAS.

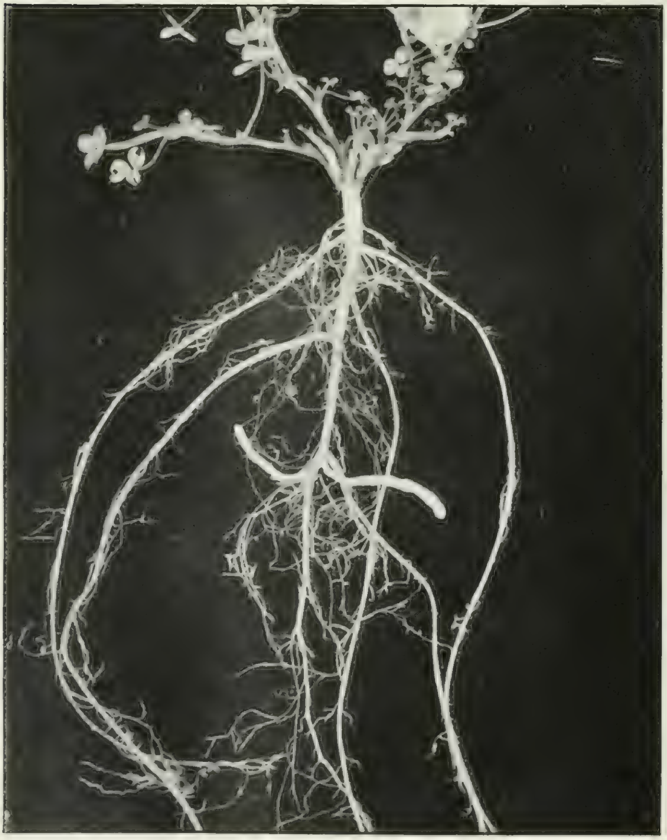


FIG. 2.—A SEEDLING OF CROSS NO. 284, SHOWING RHIZOMES DEVELOPING 3 INCHES BELOW THE CROWN 2 MONTHS AFTER GERMINATION.

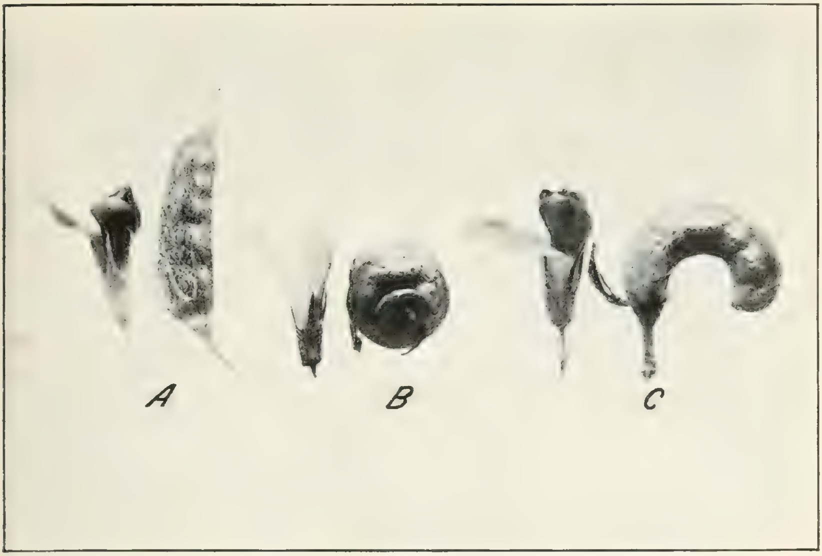


FIG. 1.—FLOWERS AND PODS OF CROSS NO. 191. *A* AND *B*, PARENTS; *C*, HYBRID.
(Enlarged two diameters.)

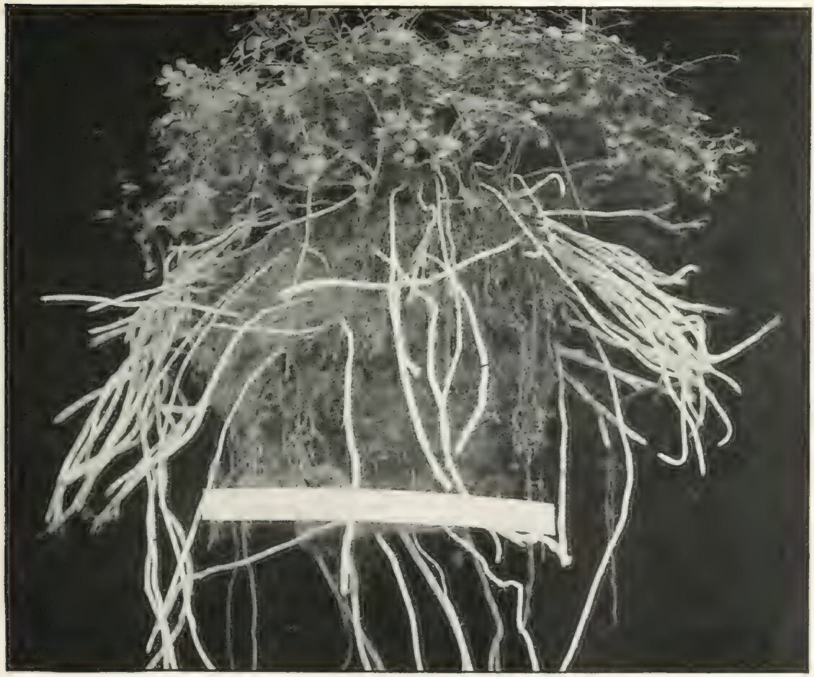


FIG. 2.—A PLANT OF MEDICAGO SATIVA (S. P. I. NO. 28152), A PROSTRATE FORM WITH ROOTING RHIZOMES, AUTUMN CONDITION.

Issued October 2, 1912.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 259.

B. T. GALLOWAY, *Chief of Bureau.*

WHAT IS FARM MANAGEMENT?

BY

W. J. SPILLMAN,
Agriculturist in Charge of the Office of Farm Management.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 29, 1912.

Sir: I have the honor to submit herewith a manuscript entitled "What is Farm Management?" and to recommend its publication as Bulletin No. 259 of the series of this bureau.

Farm management as a science and as a subject of investigation is new, and there is an insistent demand for information that will assist those who are engaged in teaching the subject, as well as those who are engaged in investigations relating to it.

This bulletin was prepared by Prof. W. J. Spillman, Agriculturist in Charge of the Office of Farm Management, and is in two parts. Part I is an outline of the science of farm management, which it is believed will be helpful to teachers in the agricultural colleges. Part II is an outline of the investigations conducted in the Office of Farm Management of this bureau. It discusses the principal problems under investigation and the investigational methods in use.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—763.

WHAT IS FARM MANAGEMENT?

I.—THE SCIENCE OF FARM MANAGEMENT.

INTRODUCTION.

Farm management treats of the business of farming from the following standpoints:

(1) Relative desirability of farming and other lines of business.
(2) Selection of the farm.
(3) Organization and equipment of the farm.
(4) Farm operation.

In the brief consideration that can be given the subject here no attempt will be made to treat of these subdivisions exhaustively; nothing further will be attempted than to make clear the nature of the subject, to present an outline of it, and to point out some of the services it can be made to render to the farmer. In the literature of the subject certain parts of farm management have received more adequate treatment than others, and these are presented here in brief outline. Other parts of the subject are newer and have not received adequate treatment in the literature of the subject, for which reason they are treated at greater length in this bulletin.

FARMING AS AN OCCUPATION.

The relative desirability of farming as compared with other occupations is largely a personal matter and must be determined by the circumstances, tastes, and desires of the individual concerned.

Considered from the standpoint of stability, safety, and profitableness there are considerable differences between farming and other lines of business. It is for the most part made up of small independent units. Farming is, perhaps, more stable and less susceptible to serious interruption from disturbances in the financial world than any other business. On the other hand, it is perhaps more dependent on the elements than any other form of business. In addition, the average profits in farming are small.

Farming does not readily lend itself to corporation methods of conducting business and is therefore preeminently a business of individual rather than corporate enterprise. In fact, farmers as a class live so much to themselves and depend so little on each other in the conduct of their business that it is difficult to secure cooperation among them even when this cooperation would be highly advantageous to those concerned. Yet the hope of the future, that the farmer may be able to cope successfully with those who are in a sense organized against him or who are in position to take unfair advantage of him, lies in the possibility of developing cooperative effort, especially in the matter of buying and selling. This is more especially true in the case of selling perishable farm products, such as fruit and truck crops.

The numerous advantages and disadvantages of country life as compared with city life, which would be considered fully in a more extended treatise, can not be discussed in so brief an article as this must necessarily be.

SELECTION OF THE FARM.

The selection of the farm is of special interest to young men who look upon farming as their life work, to those seeking a new location, and to those who contemplate moving from the city to the farm. But even to the man who already owns a farm the considerations involved in selecting a farm are of value because they are helpful in aiding him to determine the value of his own property and to judge the adequacy of the improvements on it.

This subdivision treats of all those factors that affect the desirability of a region as a general location for farming as well as those which affect the value of particular farms. It deals with the climate, the character of the soil, the availability of farm lands, transportation facilities, the social and educational conditions, the general healthfulness of the region and of the particular locality, the character and availability of farm labor, and similar questions of general or regional significance. It also deals with individual farms from the standpoint of all those features that affect their desirability and value, such as the fertility of the soil, the topography of the land, the character of the improvements, the distance to market, the distance to schools and churches, the arrangement of the fields, the location of the buildings, etc.

These questions will not be discussed at length here, since the purpose of this bulletin is to define the subject of farm management rather than to discuss fully its details.

ORGANIZATION AND EQUIPMENT OF THE FARM.

The organization and equipment of the farm is the selecting of suitable enterprises as the basis of the farm business and of fitting them together into a satisfactory system of management. Ordinarily this means a system that will permit the maximum use of power, labor, and capital within the limits of the owner's available resources; that will require a minimum of equipment with the maximum use of that equipment; and that will so distribute the labor during the season that the farmer and his available labor, both of man and beast, will be profitably occupied at all times without being too much crowded at any one time. It also involves the determination of the character and extent of the equipment required for the satisfactory conduct of the business and the installation of this equipment.

SELECTION OF ENTERPRISES, OR CHOOSING THE TYPE OF FARMING.

By a farm enterprise is meant any crop, type of live stock, manufacturing process, etc., which constitutes a part of the farm business. One of the most responsible tasks the farmer is called upon to perform is the selection of the enterprises to be conducted on his farm. On the wisdom of his choice depends very largely the financial success of the business.

Enterprises are not always chosen because of their immediate profitableness; for instance, a crop may be grown for its effect on the soil or because of some special value as a feed, but, generally speaking, the leading consideration concerning any contemplated enterprise is the prospect of its being profitable under existing conditions. The principal factor to be considered in determining whether an enterprise would be profitable in any given case is the experience of farmers generally in the region. This, however, is not an absolute criterion, for one man may succeed where another would fail. It is therefore necessary to consider the general principles that apply to the case.

As a rule those enterprises that are of large extent, such as corn, wheat, hay, dairying, hog raising, and the like, are less subject to wide fluctuations in prices than those less extensive, such as truck farming, hop culture, bean growing, potato culture, etc. It is seldom wise to base the business of a farm entirely on enterprises that are subject to violent fluctuations in prices.

Hops will illustrate this point. This is a small enterprise, taking the country as a whole, and there is not room on the markets for more than a small fraction of the hops that could be produced if all the land suited to this crop were devoted to it. Yet when prices are good the crop is highly profitable. These conditions result in eras of high prices followed by periods of overproduction and consequent low prices. In order to bring a satisfactory profit to the grower hops should sell for about 10 cents a pound. The price has been as high as $1 a pound at times, especially following a long period of low prices that caused many growers to destroy their hopyards. These high prices induce new planting, frequently great overproduction, and thus bring about a drop in prices. Hops have sold for $1 a pound one year and 4 cents a pound a year or two later, which, of course, brought ruin to the growers.

The lesson to be drawn from this is that when such an enterprise is adopted it should not be allowed to represent too large a proportion of the farm business, but should be only one of several enterprises.

The mere fact that an enterprise is small, taking the country as a whole, does not necessarily render it undesirable. Location with reference to markets has much to do in determining this point. There are many products that either because of their quickly perishable nature or because of their bulkiness and relative cheapness can not well be sent to distant markets, at least not without great expense. This is particularly true of market milk and some kinds of vegetables and fruits. Hence it follows that these enterprises are much more important in the agriculture of regions near the great market centers than elsewhere. But even where climate, soil, and distance to market render an enterprise feasible there may be market conditions that would make the enterprise unprofitable. Thus a farm may be well suited to the production of market milk, yet combinations of city dealers may fix prices in such a way as to leave the farmer little profit. Again, a farm may have soil well adapted to truck farming and be so near to market that transportation charges are unimportant, yet it is doubtful whether this type of farming is ever to be recommended to small farmers who can neither sell their produce direct to retail merchants nor take advantage of a farmers' marketing organization. Where the grower of truck crops must depend for his sales on an unknown commission merchant in a distant city, who has every opportunity to defraud the farmer, and the farmer's business is so small that he can not afford to go to the city to see that his shipments are honestly sold and paid for, truck farming is generally not profitable. Such considerations as these must not be overlooked in determining what enterprises to adopt in any given case.

It may sometimes happen that a crop is more or less eminently adapted to a particular soil type of very limited extent, or at least is vastly superior when grown on a particular soil of which the available area is relatively small. In such cases an enterprise which is small in extent and hence is subject to rather violent fluctuations in production and prices may form a much larger proportion of the business of a farm than would ordinarily be wise.

A case in point is tobacco in certain sections where a superior quality of product is grown. If the soil of a farm is such as to enable the farmer to grow a product greatly superior to the usual grades on the market and the area of similar soil is not large enough to overstock the market even if all of it were devoted to this crop, then it follows that even if there is an era of overproduction in the crop most of the product must come from land not capable of producing the best quality. The crop will have to be abandoned on such land before it is abandoned on the better soils, which will leave the markets to those who have suitable soil for the crop. Not only that, but even during eras of low prices the lowest prices will not apply to the best quality of the product, so that even when prices are at their lowest there generally will be some profit for those who produce the best quality.

The relation of agricultural enterprises to climatic conditions is so obvious as to need only the merest mention here.

Another important consideration in deciding whether an enterprise is desirable under given conditions is the cost of the necessary equipment. Many farmers, especially of the tenant class, do not keep live stock because of the expense involved in securing the necessary breeding stock and the buildings required for sheltering them. Not infrequently a farmer will be found who could find a good market for a few acres, say, of potatoes or cabbages, but who is unable to avail himself of this opportunity because of the rather expensive machinery required to produce these crops economically. These are questions that must be taken into consideration in recommending types of farming.

Closely related to cost of equipment is the amount of labor an enterprise will entail, as well as the time of year when this labor must be done. In many cases the farmer is limited in the amount of labor he can command, and an otherwise desirable enterprise may be unsuited to the conditions because it would require too much labor or labor of a kind to which the farmer is not adapted. It frequently happens that a crop may be very desirable for many reasons and yet not be satisfactory in a given case because it demands attention at the same time as some more important crop. This is probably one of the reasons why the cowpea crop has made no more headway as a separate farm crop in this country. It demands work simultaneously with corn, the most important of all our crops, and in the South interferes with the work on both corn and cotton, the two most important crops of that section. The same thing is true of soy beans.

Both of these valuable legumes have had some difficulty in finding a place in American agriculture and apparently mainly because when they are introduced on the farm they tend to crowd out more important crops that demand labor at the same time.

Sometimes crops which may ordinarily be very profitable are found to be well adapted to a given locality and even to fit well in cropping systems that give a very satisfactory distribution of labor, and yet the limited market for the product may render it unwise to develop the enterprise to the fullest extent of its possibilities. The bean crop in the upper Columbia River basin is a case in point, or at least may be. The crop succeeds well in certain portions of this area, does not interfere with the labor on the wheat crop, which is the principal agricultural enterprise of the region, and occupies summer-fallow land that would otherwise lie entirely idle during the bean-growing season. Hence, if beans were one of the standard crops of the country, representing an enterprise so large that an increase of a few hundred thousand acres would have very little effect on the relative output of the crop, it would be permissible to develop the bean industry on a large scale in this region, which seems to be so well adapted to it. But the fact is that the bean crop is a small one, and any large increase in its acreage would result in a relatively large increase in the total crop. This would seriously affect prices. For this reason the development of the bean industry in the section in question must be made only after a careful study of the area adapted to the crop and the possibilities of a satisfactory market for the product should the output increase considerably.

Finally, the effect of an enterprise on the fertility of the soil is sometimes a determining factor in its adoption. Thus, thousands of farmers maintain herds of stock which do not return market prices for the feed given them, but they do this because of the effect the manure has upon the yield of their crops. In very many cases this practice is justifiable. Suppose a farmer with no live stock except work animals could produce 35 bushels of corn per acre, while with a full complement of stock on his farm he could produce 80 bushels. Suppose he could sell his corn for 60 cents a bushel and that he can get 40 cents a bushel by feeding it; which practice, in the long run, is the most profitable? Thirty-five bushels at 60 cents is $21 per acre; 80 bushels at 40 cents is $32 per acre. Hence, under the conditions assumed, the keeping of live stock would bring $11 per acre more income than the system of selling corn on the market. This $11, however, is not all profit, for the interest on the investment in live stock and the labor cost of keeping the stock must come out of it.

Again, leguminous crops are very frequently grown because of their beneficial effect on the soil, even when some other crop might be temporarily more profitable. Thus, clover is regularly grown on hundreds of thousands of farms without direct profit but with much benefit to the land. Usually, however, the clover crop is directly profitable, but seldom so much so as corn, for instance. In a few localities the production of clover seed is quite profitable. In the South cowpeas are grown extensively as a catch crop in corn, simply for the effect on the soil. Alfalfa, the great leguminous crop of the West, is not only highly beneficial to the soil, but is frequently one of the most profitable crops the farmer can grow. It is, therefore, not surprising that in sections where this crop succeeds well it usually occupies a commanding place on the farm, much more so than clover does in its territory and vastly more so than do cowpeas in the South.

The factors which must be taken into consideration in determining the desirability of an enterprise in any given case may be summarized as follows:

(1) Profitableness, as determined by general and by local experience.

(2) The extent and distribution of the enterprise. This has much to do with the stability of the supply and demand.

(3) Location with reference to markets.

(4) Conditions existing in the market centers, especially combinations of dealers which control prices.

(5) Soil and climatic conditions.

(6) Cost of equipment required.

(7) Amount and character of labor required.

(8) Seasonal distribution of labor.

(9) Extent of a possible market for the product and the probable effect of a considerable increase in the supply on market prices.

(10) Effect of the enterprise on the fertility of the soil.

In an extended treatise on farm management each of the principal agricultural enterprises would be considered in detail from the standpoint of each of the foregoing factors.

TECHNOLOGICAL PROCESSES ON THE FARM.

A full discussion of farm organization would involve the discussion of the use of technological processes on the farm, both as a means of filling in gaps in the labor schedule and as a means of securing enhanced prices for the products of the farm. The nature of these processes will necessarily vary with climatic conditions, as well as with the type of raw materials which may be produced on the farm or may be easily procurable for such processes. Some of the leading ones conducted on American farms and therefore worthy of consideration in this connection are the curing of meats, the making of butter and cheese, and sirup making. In a treatise on farm management these processes would not be considered from the standpoint of methods of conducting them, but from the standpoint of their desirability under different conditions, the equipment and labor they require, the cost of equipment, and the financial results to be expected from them.

LABOR REQUIREMENTS OF ENTERPRISES.

The farm-management view of a crop is quite different from the agronomic view. The agronomist, or crop specialist, considers a crop from the standpoint of its requirements as a living, growing thing. It is his work to learn what effect different methods of treatment will have on yield; in short, to learn how to manage the crop to produce the largest yield. He considers the rate of seeding, the depth of planting, methods of preparing the seed bed, fertilizer requirements, methods of tillage, methods of harvesting, and the like.

In studying farm organization, which is one of the leading phases of the subject of farm management, our interest in the crop relates to the amount and kinds of labor required in the management of the crop and the equipment necessary in performing that labor. In order to formulate a cropping system that will give an equitable distribution of labor during the season, we must know the following facts concerning each crop to be used in the system:

(1) The kind and number of operations required by the crop from the beginning of the seed-bed preparation to the marketing of the product.

(2) The crews (men, horses, and machinery) that may or should be used in performing these operations.

(3) The dates between which each operation may or must be performed.

(4) The amount of work each crew should perform in a day. This involves standards of farm labor for all possible kinds of farm work.

(5) The proportion of time at all seasons of the year that can be devoted to the kind of work to be done. This requires a knowledge of the average amount of time lost because of unfavorable weather, holidays, unavoidable delays, etc.

These five classes of data concerning a farm enterprise constitute the fundamental farm-management data concerning that enterprise. Until they are made available it will be impossible to work out, except by the slow and costly methods of experience, systems of farming that will give a satisfactory distribution of labor and which will give the farmer something profitable to do at all seasons of the year, while at the same time no part of the year will be so crowded with labor as to make it difficult to get the work done in its proper season. With such data it will be possible to formulate systems that will not only distribute the labor advantageously but will greatly reduce the number of work animals necessary to farm a given area. The average farm horse in the Northern States works on the average for the year only about three hours a day. Yet at certain seasons of the year he not only works 10 or 12 hours, but the farmer seldom has enough horses to do the required work. With a properly planned cropping system it will be possible to so distribute the horse labor as to secure twice the above amount of work per horse, thus reducing by one-half the number of horses required to farm a given area.

By distributing the work in this manner it will become possible to prevent a great deal of duplication in farm implements as well. Thus, on a farm where the system of management requires the plowing of the whole farm in the spring, only a few acres can be plowed with one plow, and there must be plows as well as horses and men enough to plow the whole farm in a short time. But if the work is so distributed that about half the land can be plowed in the fall, then one plow can be used on twice as many acres in a season as under the other system. This will reduce the number of plows required.

Thus the purely farm-management data concerning the management of a crop relate to the work the crop requires and to the relation this work bears to the work required by the other enterprises conducted on the farm, or which may be introduced to advantage. Agronomy is concerned with how to treat the crop in order to get it to thrive best; farm management is concerned with how to get the work done which the agronomist says should be done.

CRITICAL PERIODS OF ENTERPRISES.

Most farm enterprises require more work at some seasons of the year than at others. The cotton crop, for instance, has two periods at which it demands an unusual amount of work—i. e., chopping out (thinning) and picking. A man can prepare the land, plant, and cultivate a much larger area than he can chop out or pick. It is customary in the cotton States for all the members of the grower's family who can handle a hoe or pick cotton, both light tasks suitable to women and children, to aid at these critical periods. Even with this help one man can still do all the other work on a much larger crop than an ordinary farm family can care for during the critical periods. It is clear that the limiting factor in the area of cotton a farmer can manage properly is the area he and his available labor can thin and pick. Where the available labor is limited to the members of the farmer's family, this area is so small in the case of the average family that a single horse can do all the horse labor required on the farm. This accounts for the general prevalence of 1-horse farming in the South. So long as southern agriculture is based as largely on cotton as it has usually been during the last generation, the 1-horse farm will be an economic necessity.

There is a better way, however, even for the cotton country. By the proper selection of enterprises the cotton grower may produce a large acreage of other crops, especially if he utilizes two horses, without cutting down the acreage of his cotton crop. But to do this it will be necessary to select enterprises that will not require much attention, if any, during cotton chopping or picking time. One of the big farm-management problems of the South is the formulation of systems of farming that will utilize the forces that now go to waste at seasons when the cotton crop does not completely employ the farmer's time and equipment.

The critical periods for the potato crop are planting and harvest. Corn is a crop that has no strictly critical period. It gives about the same amount of work at all times, from the beginning of plowing the seed bed to the last cultivation. Even at harvest time one man can gather all the corn he can grow, though it is customary to employ extra labor at this time. Generally speaking, farm enterprises have one or more periods when so much work is required that those periods determine the extent of the enterprise in any given case.

SEASONAL DISTRIBUTION OF LABOR.

Farm-management surveys conducted by Cornell University and by the Office of Farm Management have shown that, within limits, the labor income of the farmer increases with the size of his farm, and, especially on small farms, with the diversity of the enterprises followed; that is, large farms are more profitable than small ones, and farms having several kinds of products to sell are more profitable than farms having only a few kinds to sell. The reason for both of these facts is probably the same, i. e., that a large farm even when devoted to a few of the leading farm enterprises and a small farm having a large number of enterprises will ordinarily give the farmer opportunity to find profitable employment for a greater portion of the year than a small farm with only a few enterprises. In both cases, also, the farmer has the opportunity to employ more labor, both of man and beast, as well as more capital.

One of the faults of American agriculture is the lack of systems of management that will keep the farmer properly busy at all times during the year. On cotton farms in the South there are, as we have already seen, just two really busy seasons, i. e., chopping time and picking time. The area of cotton that an ordinary farm family can thin in the spring and pick in the fall is so small that it does not keep one man well occupied the rest of the year.

In many sections corn and oats are the principal crops grown. Both of these crops cause much work in the early spring, and corn gives work until time for the oat harvest early in July. But after the oats are harvested there is a period of a month or two when there is no field work to do. Examples of this kind could be multiplied indefinitely.

In almost no section of the country do the systems of farming employed furnish the farmer profitable employment during the winter. It is possible, by proper choice of enterprises and by properly gauging the magnitude of each enterprise, to organize the work of a farm in such a manner as to give profitable employment to the farmer and his available labor throughout at least the greater part of the year, certainly during the entire season when field work is feasible. Some such systems are given later in this bulletin.

While in most cases it is desirable to have systems of management designed to give profitable employment at all seasons, there are conditions under which the farmer is justified in ignoring this point. For instance, it may be possible to devote the major portion of the farm to some crop that is very much more profitable than any other crop that could be grown. In such cases, if the farmer can get all the labor he wants when he wants it, and is not compelled to support this labor when he has no use for it, a condition which is, of course, exceptional, he may be justified in growing as much of that crop as the exigencies of good soil management will allow.[1]

In some cases farmers are so situated that they can find profitable employment for their available labor in clearing land, quarrying stone, cutting and hauling cordwood or staves, etc., when they are not needed on the farm. Such men are fortunate, for in their cases one of the most difficult problems, that of formulating a system that will give profitable employment the year round, is solved in advance. But such cases are exceptional. Nearly all farmers are compelled to find employment on their own farms and on enterprises connected with the leading crops and types of live stock of the country. Since these standard enterprises tend to remain approximately equal so far as their profitableness is concerned, it follows that the larger the proportion of the year for which the system provides work the greater is the labor income.

CROPPING SYSTEMS.

It is impossible here, for lack of space, to consider all the various cropping systems in vogue in different parts of the country, or even the principal ones of the leading agricultural sections, to say nothing of outlining systems that give full utilization of the farmer's time and equipment. A few systems will be considered merely for the purpose of illustration. We shall find in their relation to the distribution of labor and the utilization of power an explanation of some of the more prominent anomalies of American agriculture.

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[1] See the article entitled "Seasonal Distribution of Labor on the Farm" in the Yearbook of the Department of Agriculture for 1911 for further discussion of this point.

We have already seen that the limiting factor in the area of cotton an average farmer can grow is the quantity the members of his family can pick. This is about seven bales. On ordinary uplands, where the yield is about one-third of a bale per acre, this means about 20 acres of cotton to the family. One horse can till this acreage, and as no other money crop is grown a farm of this size is usually a 1-horse farm. A few acres of corn are grown, but as there is only one horse and as the cotton tillage keeps him quite busy, the corn is poorly tilled and yields very little. Because the implements used are all 1-horse implements, the preparation of the seed bed for cotton, the planting, and the tilling keep the farmer busy from early in the spring until late in July. The picking then occupies the fall season quite completely. Thus, the one crop gives the farmer employment during nearly the entire season. This is one of the reasons that the single-crop system of cotton growing has persisted so tenaciously in the South; it gives employment pretty nearly as constantly as a well-planned system of farming would do, and thus enables the farmer to earn a living. The difficulty is that it does not utilize the full possibilities of the man and therefore gives him a poor living. When a man is following a 6-inch plow or a 12-inch sweep drawn by an 800-pound mule his time may be fully but not well utilized, and he is not working at his full earning capacity. What the cotton growers of the South need are systems of farming that will permit one man to employ the full power of two or, better, four horses throughout the season. This would greatly increase the earning capacity of the individual.

If the good farm lands now unused, mostly in second-growth timber, were devoted to such cropping systems the South could with its present working force grow approximately its present acreage of cotton and at the same time devote twice or three times this area to other crops. This would, of course, require a large increase in the number of work animals used as well as in implements, and this would call for much more capital than is now available to the farmers of that section. When the problems here briefly discussed have been worked out for the South and southern agriculture begins rapid expansion to its full possibilities, there will be great need of sources of agricultural credit so that the money may be had for that development.

In the Pacific Northwest there exists a peculiar system of agriculture which illustrates some of the principles here discussed. In certain sections the farmers grow little else than wheat. Unlike cotton, this crop has no critical period during which it requires a vast amount of hand labor, but can be handled from start to finish almost entirely by horse or mechanical power.

In eastern Washington the limit to the area of this crop one man can grow is the acreage of land he can prepare for seeding. In the preparation of the land one man can easily utilize five or six horses, and we actually find this number commonly used by one man. All the implements are made as large as practicable. By a further ingenious device the season for preparing the land is lengthened. A given field bears a crop only once in two years. The farmer therefore has a long time in which to prepare the land. But this time is not as long as might be expected, because the winters in that section are too wet to permit much field work and the summers are so dry that the soil soon becomes too hard to plow. But by double disking the land very early in the spring, which can be done before it is dry enough to plow, a mulch is created which keeps the soil mellow till late in June. Thus, with 5-horse teams and a comparatively long season in which to do the plowing, a large area can be prepared by one man. In fact, the typical size for a one-man exclusive wheat farm in that section is about 320 acres, on which 160 acres of wheat are grown annually. Managed in this way, a wheat farm gives the farmer plenty of profitable work to do from early in the spring until nearly harvest time. Then the harvest season gives another long period of work. In that region the varieties of wheat grown will stand several weeks after they are ready to cut, so that the harvest season is greatly prolonged, and with the system of harvesting in vogue there is no trouble about getting all the wheat cut and thrashed that a farmer can grow. When harvest is over it is about time to begin sowing a new crop on the land that was plowed in the spring.

Thus, the system followed not only enables a man to utilize much power but it gives work through a considerable portion of the season. Under normal conditions this system of farming is quite profitable, and many farmers have grown quite wealthy in the wheat business. But there are dangers in the system, as the farmers very well know. Once for a period of three years the price of wheat was so low as to cause heavy losses. It is also probable that another generation of this type of farming would result in soil depletion to such an extent as to be disastrous.

This system does not use all the time and power one man could employ, and it leaves half the land idle every year. Methods of obviating these difficulties are now being worked out for certain localities, but it would require too much space to detail these here. Enough has been said to show why the farmers have clung so tenaciously to this system of farming in the face of urgent persuasion on the part of those who saw the defects but not the excellencies of the system.

The essential difference from an economic point of view between the prevailing methods of growing cotton in the South and wheat in the Palouse country is in the amount of horsepower one man can use in the two cases. The fact that machinery is not yet used for the most critical period of the cotton crop—the picking—and that the area of this crop a family can grow is therefore limited to what they can pick, and that this area is very small, renders it impossible on an exclusive cotton farm to profit by the possibility of using more power in plowing and in cultivation.

On the other hand, what was formerly the critical period for the wheat crop—the harvest—when this had to be performed by hand, is now not a limiting factor, for the farmer can get wheat harvested and thrashed from all the land he can plow, harrow, and sow. The real limit to the area of wheat one man can grow is the area he can plow in season. In this work he can readily use the power of five horses. For this reason he is able to farm a much larger area and secure a much larger income than the cotton grower.

The only way the cotton grower can get into the class of the wheat grower from the standpoint of income is by hiring a large amount of human labor at low wages for the two hand operations the cotton crop requires. As a result of this condition, most of the cotton is grown under a tenant system by poor people, while wheat is grown by the owner of the land himself, who is usually a well-to-do farmer. This applies, of course, only to those localities where the methods outlined are practiced.

A financial comparison of the two one-man systems of farming is shown in Table I.

Table I.—*Comparison of two one-man systems of single-crop farming.*

Crop.	Charges.			Income.	
	Rent.	Interest and depreciation on equipment.	Total.	Gross.[1]	Labor.[1]
Cotton	[2] $72	$15	$87	[3] $350	$263
Wheat	[4] 1,152	165	1,317	[5] 2,880	1,563

[1] The farm expenses other than rent, depreciation, and interest on crop equipment are not here taken into account. Hence the labor income given is not the net income.

[2] Twenty acres at $3.60.

[3] Seven bales from 20 acres.

[4] Three hundred and twenty acres at $3.60.

[5] Four thousand eight hundred bushels (from 160 acres) at 60 cents.

Thus the possibility of using more power in the one case not only gives a much greater labor income, but the possibility of using more capital gives a correspondingly greater interest income.

Until the problems of thinning and picking cotton by machinery are solved the one-man farm must continue to bring only a bare living to the man who grows the cotton, provided he grows little else.

There are two alternatives for the cotton grower. In order to use more capital and more power and thus increase his income, he must either employ a great deal of cheap human labor or change to a system of farming that will permit him to use more power for those operations on the cotton crop which permit it, such as plowing and cultivating, and devote the time thus saved to other enterprises which also permit the use of a maximum of power. It is the province of the newly developing science of farm management to work out such systems for the cotton country.

While the two systems of farming just described are distinctly faulty and have been condemned by the best authorities, the fact is that, considered from the standpoint of labor distribution and the full utilization of a man's abilities, they are not much worse than the systems that prevail quite generally over the country. In fact, the system of wheat growing outlined utilizes a man's possibilities to far better advantage, and so long as the soil holds out and the price of wheat is satisfactory is far more profitable to the farmer than the systems prevailing in most parts of the country.

In general, even in the case of single-crop systems like those described, and more especially in the case of the more complex systems prevailing in the corn belt, the systems of farming that have been worked out by the cut-and-try method of experience will be found to give a first approximation to good seasonal distribution of labor and full utilization of equipment. This is necessarily so, for if it were not the case the farmers would long ago have been forced out of business.

The systems that have survived represent a sort of natural selection in which those that furnished the farmer a living survived, while the others disappeared. It is not exactly the survival of the fittest; it has been rather the elimination of the utterly unfit. Especially does the rotation of corn, wheat, and hay approach an ideal distribution of labor and use of equipment when the area of the farm happens to be just right and when the rotation is properly arranged. Thus a 6-year rotation of corn, corn, wheat,[1] wheat,[1] timothy and clover, timothy and clover gives a distribution of horse labor that is almost absolutely uniform from early in the spring until late in the fall. This keeps every needed horse busy and obviates the necessity of hiring extra horses as well. This system calls for extra man labor at wheat harvest, hay harvest, and in the corn harvest, but at other times the amount of man labor needed is just the same at all times.

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[1] Fall sown. This rotation is adapted only to middle latitudes.

The area one man can farm with such a system is limited by the following factors:

(1) The area of corn land he can prepare for planting.
(2) The area of corn he can till.
(3) The area of wheat land he can prepare in the fall.

Fortunately, these three factors are equal. With two good horses one man can handle 40 acres of each of these projects. Hence, with this system he can farm 120 acres of arable land without extra labor except at harvest time. With four good horses it would seem that one man ought to farm 240 acres in this rotation, though this has never been even approximated in practice, so far as the writer knows. One farmer has been found who is actually farming the 120 acres that theoretically he should be able to farm with two horses.

The type of rotation found most generally on farms in the region to which this rotation is adapted is a first approximation to this one, which gives an ideal distribution of labor and reduces equipment to a minimum. These rotations are practically always some form of the general one of corn, small grain, timothy and clover. But since the farmers generally have not the data to work out the labor distribution of a system accurately—indeed, no one has this information sufficiently exact—the actual systems in vogue are only rough approximations of what they ought to be.

Another system of rotation that gives an even distribution of horse labor, so that a minimum number of horses can do the work of the farm, and that requires extra man labor only at harvest time, while at other times the regular help is kept reasonably busy at remunerative employment, is corn, corn, cowpeas (or soy beans) sown broadcast, wheat, wheat. With two good horses one man can manage 75 acres in this rotation; with four horses he should manage 150 acres. Reference is here made only to the field work. This last rotation would furnish cowpea hay, straw, and corn stover, all of which could be used to advantage as feed for live stock, especially dairy cows. A good herd of cows furnishes labor equally distributed throughout the year, so that a dairy farm with the rotation mentioned would represent an excellent system from the standpoint of the distribution of labor and economy in equipment.

Generally speaking, any cropping system which has stood the test of time and prevails pretty generally over an important agricultural region will be found to give at least an approximation to uniform distribution of labor with minimum equipment. But when the farmers in a region where rather poor farming is done attempt to break away from prevailing practice and begin to invent new rotations, under the impression that rotation farming is an improvement over the prevailing methods in their locality, the crude rotations often resulting are frequently very far from satisfactory from the standpoint of equipment and labor distribution. It not infrequently occurs in such cases that the new system necessitates the plowing of all the land on the farm in the early spring. To do this requires an army of horses and plows as well as plowmen. The plowmen can be hired temporarily, but as a rule the farmer must own the plows and horses. He must also be supplied with harrows, cultivators, etc., to correspond. After the rush of spring work is over nearly all of the horses and equipment stand idle for most of the season. Such systems do not last long and never become general in a region.

Enough has been said here to show that the work of reorganizing the agriculture of a region that for any reason is in an unsatisfactory condition is a task worthy of the best minds in the country. The farmers, unaided by the scientific investigation of the subject, will finally reach an approximate solution of the problem, but the process will be so slow that by the time this approximation is reached changed economic conditions may have rendered the new systems worked out by the farmers unsuited to the then existing conditions. Hence this is the work of the agricultural scientist, and the investigator is confronted by no more important or difficult task than that of farm reorganization. It is practically a virgin field. The fundamental data on which such work must be based are not yet at hand. The present task of the farm-management investigator is to secure these data.

THE AREA ONE MAN CAN FARM.

Of the factors that determine the size of the one-man farm the most important is the enterprises adopted, and, as we have just seen, it is the critical periods of these enterprises that are important in this respect. But the extent of a single enterprise that one man can manage depends on a number of factors, the most important being the character of equipment used.

In most sections of the country it is customary to employ temporary labor during critical periods, especially at harvest time. With cropping systems that require only extra man labor at critical periods and no extra horse labor, and where it is possible to arrange such systems, it is usually quite feasible to increase the acreage farmed to the largest area that the available horse labor will provide for, since it is usually possible to secure extra man labor, even when extra horse labor can not be had. Where extra man labor can be had at harvest time, then the area farmed will depend on the number of horses one man can utilize. In many cases it is practical to do almost all the field work with 4-horse teams. To do so, of course, doubles the area one man using a 2-horse team can farm.

The length of the season during which field work can be done also influences the area a given force can farm. In sections where the field work can begin in the very early spring, as it can all over the South, one team can prepare more land for seeding than in sections where the spring season is short, as it is in the northern tier of States. On the other hand, the heat during summer in the Southern States tends to reduce the acreage that can be tilled by a team.

The character of the soil also affects the area a team can plow and till. On light sandy soils a team can cover more ground at most operations than on heavy clay soils. The presence of stones, as in many New England fields, and the presence of roots and stumps, as in newly cleared land, also reduce the area that can be farmed. On irrigated land the area a given force can farm is smaller than on nonirrigated, for the irrigating takes time, and the presence of ditches in the fields, causing frequent turning on short rows, reduces the area that can be covered in a day.

Uniformity of equipment is another factor often overlooked. On a 4-horse farm it is a waste of time to have part of the field implements of a size adapted to two horses and another part to three. By using only 4-horse implements in so far as this is practicable the time of one man is frequently saved, or if only one man is available the constant use of 4-horse implements greatly increases his efficiency. One of the problems to be worked out by farm-management investigators is the practicability of using implements of uniform size for field work, especially the sizes that utilize the largest possible amount of power, or at least all the available power on the farm.

RELATION OF MAGNITUDE OF BUSINESS TO PROFIT.

Profit in farming depends not only on the intrinsic profitableness of the enterprises adopted, but also to a great extent on the amount of power employed and the amount of capital invested. If there is profit in an enterprise conducted on a small scale, there ought to be more profit in it when conducted on a larger scale. A system of farming that limits the farmer to the use of one horse gives less opportunity for a large income than one that permits one man to use four or five horses to advantage. A comparison has already been given of two types of farming which illustrate this. Any system of farming that limits the worker largely to what he can do with his hands, without the aid of horse or mechanical power of some kind, will, as a rule, bring small returns, and those who follow it will have incomes little, if any, larger than ordinary wages. At least in the case of crop products grown for sale the amount of horsepower the grower can utilize to advantage is an index to the labor income a man can make single handed—i. e., on a one-man farm.

In order to secure the larger use of power and capital either of two methods may be pursued. In localities near the large market centers and on some farms near smaller centers the more intensive types of farming may be instituted, in which the amount of work to be done on a given area is large and in which much capital may be advantageously employed. In localities where such intensive enterprises are not appropriate because of lack of a suitable market for the products the best means for the farmer to employ to put himself in a position to use more capital and employ more power is to increase the size of his holdings either by purchase or by renting. Some of the most prosperous farmers in the country are farming rented land. These are men whose capital is too small to permit them to own large tracts of land, and they wisely lease as large an area as their capital will permit them to equip and farm properly, thereby securing the possibility of using much power with comparatively little capital.

The size of the farm should, if possible, be large enough to permit the farmer to use as much power as his capital renders possible, whatever the type of farming adopted.

THE NORMAL SIZE OF FARMS.

In those sections of country where the farmers must in the main depend on the ordinary field crops and the common types of live stock the normal size of the farms may be assumed to be such as to give full employment to the number of horses worked in one team to the best advantage. As 2-horse teams are much more commonly used than any other in most parts of the corn belt, it would naturally be expected that the 2-horse farm, or rather the farm that would keep one 2-horse team busy with the field work, would be the most practicable size for which to formulate a satisfactory working plan. It must be remembered that the average farm is not very well planned, and that for this reason one team does not ordinarily do the field work for areas as large as those above shown to be possible with a well-planned system.

In this connection the statistics concerning the relative numbers of farms of different sizes as given in recent data of the Bureau of the Census are of great interest. We should expect to find that those sizes of farms would be most frequent that permit fairly good organization with the least difficulty. This means, in the corn belt, the 2-horse farm. Farms smaller than the full capacity of two horses would not give full employment of labor and equipment when ordinary field crops are grown, and in the corn belt generally these are the leading enterprises of the average farm. Hence, these smaller farms would not be so profitable, or rather it would be more difficult to make them profitable, and the number of the smaller farms would tend to decrease while the farms of a size adapted to easy organization along economic lines would increase in number. The facts as to this point are given in Table II for some of the leading corn-belt States.

TABLE II.—*Change in sizes of farms in the corn belt.*

[Sizes which are increasing in number are marked plus (+), those decreasing in number are marked minus (−), and those stationary are marked with a point (⊙).]

States.	Sizes of farms (acres).								
	3 to 9	10 to 19	20 to 49	50 to 99	100 to 174	175 to 259	260 to 499	500 to 999	1,000
Indiana	+	+	−	−	+	+	+	−	⊙
Illinois	+	+	−	−	+	+	+	−	⊙
Iowa	+	+	−	−	+	+	+	−	⊙
Wisconsin	+	+	−	−	+	+	+	−	⊙
Michigan	+	+	−	+	+	+	+	⊙	⊙
Ohio	+	+	−	⊙	+	+	−	⊙	−

The table shows that the two smaller sizes of farms are increasing in numbers in all six of the States specified. These small farms are undoubtedly mostly truck and fruit farms and hence are organized in an entirely different way from those devoted to the standard field crops. These small farms are not as numerous in this division of States as they are farther east, but are increasing practically everywhere to some extent, to meet the growing demands of the cities for fruit and vegetables.

The next two sizes of farms are decreasing in numbers. They are too large for gardens and not large enough for farms under the average conditions prevailing in these States. In the older States to the east these two sizes are on the increase for the reason that there the problem of suitable organization of these intermediate-sized farms has been better worked out.

The next three sizes, including farms of 100 to 500 acres, are all increasing in these corn-belt States. This is because their size lends itself to easy organization on economic lines with the enterprises that are best adapted to that region.

Farms larger than 500 acres are either not increasing in numbers or are actually decreasing. These figures well illustrate the fact that farms either smaller or larger than those we have here called normal-sized farms are difficult to organize satisfactorily and consequently have not generally been so successful as the better organized normal-sized farms.

The acreages in Table II are for the whole farm, including a good deal of land not actually farmed. The census data do not give the area of land actually under cultivation on these farms, but it is known to be somewhere near two-thirds of the areas given in that table.

In this region of corn, wheat (or oats), and timothy and clover the 125 to 160 acre farm is not only increasing in numbers more rapidly than any other size, but it already constitutes by far the most numerous group in most of these States.

The problem of the farm of intermediate size (20 to 99 acres) is an exceedingly interesting one. When such a farm, with, say 40 to 50 acres of arable land, is devoted to the ordinary farm crops, it utilizes neither the farmer's time nor his equipment to its full capacity. In order to make such farms profitable it is necessary either to add some such industry as dairying or to substitute for part of the field crops more intensively worked crops, such as fruit and vegetables. These types of farming find their opportunity largely in the vicinity of large cities; hence, we naturally find farms of this size in the older States near the great market centers.

REDUCING THE COST OF PRODUCTION.

The full utilization of equipment is an important means of reducing the cost of production, since it reduces the amount of equipment necessary. The average farm horse in the Northern States works only three hours a day. This is because the system of management on the average farm is so poorly planned that at certain times the work is very heavy, while at other times there is nothing to do. It is necessary to keep horses enough to meet the needs of the farm when the work is heaviest, but at other times these horses are idle. The average cost of horse labor on the farm under these conditions is about 10 cents an hour. With a well-planned cropping system that distributes the farm labor equally throughout the season it is possible to get six hours' labor per day out of the horses. When this is done the cost of horse labor per hour is reduced to 5 cents.

Many a $12 plow is used to plow not more than 10 acres a year. At this rate the cost per acre for the use of the plow is about 18 cents. When the same plow is used to plow 40 acres a year the plow cost per acre is reduced to about 5 cents, or less than one-third what it is when the plow is used on only 10 acres. Approximately the same thing is true of all other items of equipment. On poorly planned farms the equipment cost is excessive because each item of equipment is used to less than its capacity. For the reason that the equipment must be sufficient to do a great deal of work in rush periods the amount of equipment on poorly managed farms must be much larger than on well-managed farms where there are no rush seasons. On the latter type of farms the work is well distributed, so that no great amount of it must be done at the same time, thus making possible a minimum of equipment.

These are all arguments for well-planned systems of farming. One of the greatest strictly farm-management problems is that of working out such systems in all sections of the country for farms of all sizes and types.

THE FARM GEOGRAPHY.[1]

Another chapter under the general heading "Organization and equipment of the farm" relates to the layout of the farm, or its subdivision into fields, pastures, wood lot, farmstead, etc. No extended discussion of this phase of the subject will be given here, since the title of this chapter is self-explanatory. Reference to it is made here to show its place in a logical arrangement of the subject matter of farm management. The subdivision of the farm into fields is determined largely by the type of farming and the particular enterprises constituting the basis of the farm business. The topography of the land, especially where it is more or less hilly, is also a factor. The size and shape of the farm also help to determine the most suitable arrangement of the fields.

THE FARMSTEAD.

The location of the farmstead, i. e., the group of farm buildings and the yards, lots, garden plat, and kitchen orchard that naturally accompany them, depends on the size of the farm, the location of near-by roadways, the topography of the land, and the prevailing direction of the wind. Since this bulletin is not a treatise on farm management, but rather an outline of that subject, and since the pertinence of this part of the subject is easily apprehended, no further discussion will be given here of the factors determining the location of the farmstead or of the plan of arrangement of its various parts.

FARM EQUIPMENT.

FACTORS OF PRODUCTION IN AGRICULTURE.

The factors of production are classified by economists as land, labor, and capital. This classification is not satisfactory in the consideration of agricultural production for the reason that land itself represents the larger part of the farmer's investment and hence must be considered as a major item of his capital. Furthermore, in practice a different classification of the equipment necessary in agricultural production is well established. For purposes of taxation and in the buying and selling of farms it is customary in this country to divide farm property into real estate and personal property. It will therefore be most satisfactory in discussing the subject to follow the classification of farm property already in general use. Accordingly, we may classify the factors of production into the following three general groups, with their subdivisions as indicated:

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[1] Many valuable suggestions relating to this and other farm-management subjects may be found in Bulletin 236 of the Bureau of Plant Industry, entitled "Farm Management: Organization of Research and Teaching," by W. M. Hays, Andrew Boss, A. D. Wilson, and Thomas P. Cooper. 1912.

I. Real estate, or the land and its permanent improvements.
  - Land.
  - Dwellings.
  - Other farm buildings.
  - Fences.
  - Drainage systems.
  - Water supply.

II. Personal property, or the working capital.
  - Live inventory.
    - Work animals.
    - Other live stock.
  - Dead inventory.[1]
    - Implements and machinery.
    - Circulating capital.
      - Supplies and stores, such as feed, seed, fertilizers, unmarketed stock and crop products, fuel, etc.
      - Cash (or credit) used for current expenses.

III. Labor.

Of these factors, land is properly considered under the second subdivision of the subject of farm management, i. e., "Selection of the farm." The remaining factors all belong properly under "Farm equipment," which is logically a part of the subject of farm organization. No attempt will be made in this brief presentation of an outline of the general subject of farm management to discuss each of these factors in detail. A brief discussion of the cost of farm dwellings is given merely to illustrate the general method of attacking problems relating to farm equipment.

COST OF THE FARM DWELLING.

How much money can the farmer afford to put into his dwelling? At first thought this question seems to admit of no definite answer because of the number of factors entering into the case, but it does admit of a perfectly definite answer, as will be seen.

The average cost of farm dwellings is controlled by two opposing forces. One of these is the pride of the farmer and his family and the natural and commendable desire for the comforts of life. This force tends to raise the cost of the dwelling. On the other hand, the farm income must suffice not only to defray the expenses of running the farm, but also the living expenses of the farm family.[2] The farm income must also, in the long run, build the dwelling. If too much money is expended in erecting a dwelling, then the sum available for defraying the expenses of the farm and the farm family will be reduced to the point of being inadequate. The exigencies of meeting farm and living expenses therefore represent a counter force which tends to lower the cost of the dwelling. In the study of farm equipment, instances have been found in which the farmer had expended so large a sum on his house that he was seriously handicapped in the management of his farm because he could not afford to buy much-needed implements and machinery.

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[1] "Dead" is used in the sense of inanimate. This is the term always used in German textbooks on farm management.

[2] Cases in which the family has other sources of income are not here considered

In the long run, i. e., on the average of a large number of cases, the point of equilibrium between these two forces will represent the proper cost of the farm dwelling, or rather a cost that to exceed would be unwise. Studies of this subject have been made in several parts of the country and the results have always been the same. The average cost of the farm dwelling is equal to the annual sum available for the living of the farm family, including that portion of the living represented by supplies obtained from the farm; in other words, it is equal to the net farm income for one year. There are probably sections of the country where for special reasons, such as depreciation of farm values or the decadence of agriculture, this rule does not hold, but it will probably be found to hold quite generally where agriculture is in a stable condition and where farmers generally have no other source of income than their farms.

Most of the other classes of farm equipment lend themselves to study in the same manner as do farm dwellings. The Office of Farm Management is now devoting a great deal of time to such studies, and the results should be of much value to farmers.

In the matter of farm labor, which is listed as one of the factors of production, the discussion of the amount of labor needed under different conditions in farming belongs properly here under farm organization. The management of labor is treated later in connection with farm operation.

FARM ADMINISTRATION AND OPERATION.

SYSTEMS OF OPERATION.

The first question to be decided in undertaking the administration of a farm is the system of operation to be adopted. The principal systems are:

(1) Proprietary system—
  Operation by the owner and his family, with or without additional hired labor.
(2) Managerial system—
  Operation by hired labor managed by the owner or a hired manager.
(3) Tenant system, with or without supervision—
  Share tenants.
  Cash tenants.
(4) A combination of two or more of the above systems.

In rural economics these various systems of operation are considered from the standpoint of the community or the State. The effect of each system on the character of citizenship and the general economic effect of the wide adoption of any system would be considered by the economist. In farm management we are interested in these systems from the standpoint of their practicability under given conditions and from the standpoint of their effect on the income of the owner of the farm. This includes their effect on the fertility of the soil, since this is an important factor in making the farm profitable. From the viewpoint of the farm manager the question is, What system of operation is most practicable under my conditions, which will give the largest net income, and what effect will the system have on the future yielding power of the soil?

TENANT FARMING.

The most important feature of tenant farming from the farm-management viewpoint is the character of the contract between landlord and tenant. This is a very real problem to every one who rents land, either as owner or as tenant. The owner naturally wants all he can get for the use of his land and its improvements; the tenant just as naturally wants all he can get for his labor. The one great fundamental point on which all other details of the contract hinge is the proportion of the income of the business that should go as remuneration to labor and the proportion that should go as interest and depreciation on the invested capital. When this point is once determined it is an easy task to work out the remaining details, no matter what proportion of the working capital is furnished by landlord and tenant, respectively.

The proportion of the farm income that should go to labor will vary with the type of farming and with the fertility of the soil. This point is now under investigation by the Office of Farm Management, and it begins to appear that it will be possible to arrive at a few general principles that have very wide application and that will furnish a satisfactory solution for this vexed problem.

Aside from the division of income between labor and capital, the most important feature of the contract is the length of tenure for which it provides, though this is not usually considered as important as it really is. On this point depends very largely the effect of tenant farming on the fertility of the soil. With the usual form of lease contract the short-term tenant has no financial interest in what the farm may be able to produce after his lease expires. He is interested in getting out of the land all it will produce now, and does not care very much whether the soil is left in better or in worse condition than before. On the other hand, the long-term tenant has an interest in the future yielding power of the soil. Short-term tenantry is highly undesirable from every point of view. This difficulty might be obviated, as it now is in England under the Agricultural Holdings Act, according to which a tenant on giving up a holding must be remunerated for any unexhausted improvements he may have made during the life of his lease, when these improvements have been made with the consent of the landlord.

Whether the contract between the landlord and the tenant shall be reduced to writing or shall merely consist of a verbal agreement is a question to be determined by the circumstances of each individual case. In some cases one method is best and in other cases the other. Space will not permit detailed discussion of this point.

It is assumed that the landlord shall furnish the land with the necessary permanent improvements and that the tenant shall furnish the labor. Aside from this, the principal points to be covered in a lease contract are as follows:

Items of working capital (supplies and movable equipment, including both live and dead inventory) to be furnished by each party.

Share of each party in the income of the farm or the amount of rent to be paid and the conditions of payment.

Items relating to soil management, including restrictions as to the cropping system to be used, the amount and kind of live stock to be kept, and the method of utilizing crop products.

Repairs of permanent equipment.

Length of tenure.

Tenant's privileges, such as keeping cows, pigs, and poultry, raising garden truck, and the use of supplies from the farm, including fuel.

Amount of supervision by the owner.

The general method of investigating this whole problem is that outlined in treating of the farm dwelling. It consists of a careful study of actual contracts all over the country, with special attention to the satisfactoriness of the various details, both to landlord and to tenant. A contract that enables the landlord to secure and keep a desirable class of tenants is taken to be satisfactory from the standpoint of the tenant; one that does not satisfy good tenants and under which they decline to remain after having had experience with it is considered unsatisfactory.

The cost and character of tenant houses, as well as their location with reference to the main dwelling, are subjects of some importance in farm operation and would receive attention in a treatise on farm management.

While it seems probable that tenant farming will increase as the value of farm land rises in this country, it is hoped that the work of the agricultural scientist may serve in some measure to counteract this tendency.

HIRED LABOR.

The subject of hired labor as a part of the general subject of farm management takes up such questions as the supply of farm labor and the sources of this supply; wages and the methods of paying them, both to regular employees and to temporary day laborers; profit sharing; housing and boarding laborers; the laborer's privileges, such as the use of horses and vehicles, holidays, and trips to town, access to papers and books, and the social status and welfare of farm laborers from the standpoint of securing continued service from desirable laborers.

In the management of labor it is important that the manager have accurate knowledge of the standards of farm labor. If both manager and laborer understand this matter the management of labor is greatly simplified. Hence, in the management of labor it is well not only for the manager to inform himself on this subject but to make use of such data on the subject as are available as a means of educating the laborers he directs concerning what may fairly be expected of them. No one has a moral right to demand that the laborers under his direction shall work at a rate that would impair the working power of the laborer, but with this limitation the manager has a right to expect the best service the laborer can give.

THE WORK SCHEDULE.

On a farm that has a definite cropping system, and in fact on any farm as soon as the plans for the season are definitely made, it is possible to make out at least a rough schedule of the work to be done during each month of the coming season. A very good plan is to divide each month into three periods, the first and second periods being 10 days each and the third the remainder of the month, which will make the third period 8, 10, or 11 days according to the length of the month. A chart can then be made having the dates in the left-hand column and the various crops or other enterprises for the headings of the remaining columns. Under each heading may be inserted in each 10-day period the work to be done on that particular enterprise during that period. It will, of course, not be possible, on account of the vagaries of the weather, to follow such a schedule blindly, but at the same time the schedule will be of great service in keeping track of the farm work. It is especially helpful as a means of foreseeing what equipment as well as what teams and men will be needed at particular times and this enables the manager to be prepared for work at the time it should be done.

Such a schedule is also helpful in the management of labor, especially of those who are inclined to shirk. If the schedule is based on generally recognized standards of farm labor the laborer who fails to keep up with it is thus shown to be not doing efficient work.

It is also a good plan in connection with the work schedule, or even where no definite schedule is maintained for the ordinary field work, to keep on hand a list of things to be done at times when, on account of the weather, the field work is interrupted.

CARE AND UPKEEP OF EQUIPMENT.

This part of the subject deals with such questions as keeping implements and machinery in repair and protecting them from the weather; the importance of having implements in order when the necessity for using them arises, instead of waiting until they are needed, and thus causing delay in their use; methods of keeping track of the supplies and the importance of having things on hand when needed, instead of having to stop work and waste time in going to town to get them; the losses occurring from careless handling of small tools and minor items of equipment, and methods of preventing such losses: the repair of farm buildings and their protection from fire; the importance of keeping drainage systems in repair; the principal difficulties that arise in connection with such systems and how to avoid or meet them; and the management of the water supply.

FARM BOOKKEEPING.

The keeping of records of the farm work and business transactions is a very important part of farm administration. It is true that many farmers, even successful ones, do not keep any formal records, but this does not mean that they know nothing of the status of their business. When the business is not extensive or complex most farmers are able to carry the details in their heads sufficiently well to answer practical purposes. But when the business is large and complex, and especially when it involves a good many running accounts with parties with whom business is transacted, more or less formal record making becomes quite essential.

The leading classes of farm records, each of which would receive more or less consideration in a treatise on farm management, are the inventory, the financial accounts, the labor records, the performance records (such as milk records of individual cows, etc.), the feeding records, cost accounting, the record of supplies, the weather record, and the breeding records.

PURCHASING SUPPLIES.

There are a few general considerations relating to the purchase of supplies and farm necessities that should be set down in a treatise on farm management. Some of these are the advisability of buying for cash, the saving by buying in quantity, the value of promptness in meeting obligations, etc. In a mere outline of farm management it is unnecessary to enter into details in the discussion of these considerations.

MARKETING PRODUCTS.

This is another subject that requires no extended mention in an outline of the subject of farm management, but should receive due consideration in a complete treatise on the subject. The necessity of putting up in an attractive manner any farm product that is to be sold directly to retail customers in the form in which it leaves the farmer's hands is so obvious that it ought not to need discussion, yet when one goes to market and sees unsorted and unattractive apples and potatoes exposed for sale beside the products from farms that send only attractive wares to the market, it seems that farmers have not yet generally learned this lesson. The unwisdom of trying to market perishable farm products, such as the softer fruits and truck crops, through unknown and unrecommended commission merchants in distant cities, who have every chance to practice fraud without let or hindrance, ought also to be so self-evident as to prevent anyone from relying on such methods of marketing; but the facts indicate that many have not learned this lesson, and some farmers apparently need to have the lesson repeatedly brought to their attention.

STORAGE AND CARE OF FARM PRODUCTS AND SUPPLIES.

The depredations of insects and vermin on stored farm products in some sections are serious. Methods of preventing these depredations are of importance to the farm manager. Losses from exposure to the weather, especially in the case of such products as hay and fodder, are also subjects to be considered in discussing farm operation.

CROP AND SOIL MANAGEMENT (APPLIED AGRONOMY).

The difference between the farm-management point of view and that of agronomy, relating to crop management, has already been pointed out. Farm management includes the application of the principles of agronomy in business. It also includes the application in practice of the principles of soil management, if, indeed, soil management is not to be considered simply a phase of crop management.

In actual practice it is frequently necessary to depart from the teachings of the agronomist, for the reason that to give each crop the care which the agronomist has shown to be desirable from the standpoint of the individual crops is not always feasible. Thus, it may be desirable to use both oats and corn in a rotation, in which to give the oats the best possible opportunity is incompatible with the interests of the more valuable corn crop. There is little doubt that on the average oats will give better yields if the soil is plowed and put in excellent condition before the oats are sown. But to do this would greatly reduce the area of land that could be made ready for corn, since these two crops compete with each other for labor at the same season of the year. But if the oats are disked in on corn stubble without any previous preparation of the land, experience has shown that they do fairly well in some sections, and, since this can be done before the soil is in condition to plow, the full quota of oats can by this means be sown in the rotation without interfering with the preparation of the soil for corn. In farm management, therefore, we are not only interested in knowing what are the best methods of crop and soil management from the standpoint of securing maximum yields, but also what the result will be when departures must be made from the practice that would give maximum yields.

The maintenance of soil fertility is one of the most important problems confronting the farmer, at least in the older farming regions, and will ultimately be everywhere. We know very well that plenty of barnyard manure will build up infertile soil and maintain fertility in an already rich soil. But not every system of farming provides sufficient manure for this purpose. When manure is not available or is available in insufficient quantity provision must be made in most sections for some other means of keeping up yields. These other methods are much less well understood than the method of using manure. Provision can usually be made for supplying humus by growing catch crops at various points in the rotation practiced and by plowing under as much as possible of the refuse of the crops grown, especially the stubble of perennial hay crops. But this alone generally will not suffice, so that in default of abundant manure it is usually necessary, except in the more newly settled regions, to resort to the use of commercial fertilizers. It is an interesting question which the next generation of farmers may have to face, What will take the place of commercial fertilizers when the supply of phosphates and potash salts is exhausted?

One of the very important farm-management studies is to work out the relation between all kinds of practices to the maintenance of soil fertility. This problem is amenable to study by the experimental method, but the study of farm practice where applicable is not only cheaper and quicker but rightly conducted is much more accurate than the ordinary field-plat experimentation because of the much greater mass of data and the greater certainty that the results obtained will be applicable to actual farm conditions. This study should include the farm methods of managing manures as well as farm practice in the use of catch crops and of commercial fertilizers.

LIVE-STOCK MANAGEMENT (APPLIED ANIMAL HUSBANDRY).

Animal husbandry bears the same relation to farm management as does agronomy. In farm management we are interested in the application in practice of the principles of animal husbandry. Farm-management investigations do not properly include experimental work in either agronomy or animal husbandry, but they do include farm-practice investigations in both these subjects. It is one thing to discover a scientific fact in the laboratory and a very different thing to work out its application in practice. It is the latter phase of these two sciences that is of direct interest in farm management, and this phase can only be studied by the actual investigation of farm practice.

In farm management both crop and live-stock management are considered especially from the standpoint of complete systems and the bearing these systems may have on the remainder of the farm work.

STUDY OF SUCCESSFUL FARMS.

For the reason that many principles of farm management can only be studied in farm practice, the careful farm student or manager will study those that are distinctly successful. The student will learn much that can not well be set down in books and formal lectures, and the farm manager will find in the experience of others the solution of many problems that arise in practice that are never thought of in the classroom.

It is difficult to formulate definite plans for the study of actual farms. No two farms are alike, and a set of blank forms intended to bring out the salient points in the management of a particular farm will seldom suffice for another farm. Such studies should begin by getting a general view of the system of management in vogue on the farm. A very good plan of procedure is to get first a statement of the cropping system, including the acreage and yield of each crop usually grown, the rotation practiced, if any, and the use made of each crop. Then may follow a statement of the system of management of each crop, including complete details regarding the use of manures and fertilizers, the dates of plowing and seeding, the number of cultivations, etc., for each crop. Next may follow similar treatment of each type of live stock on the farm. After this, if any technological processes are followed, a complete account of them should be obtained. In obtaining an account of any enterprise the aim should be to secure a statement of every operation performed, the season of the year when it is performed, the amount of work it requires, and the equipment used in this work, including the number of men and horses and the kind and sizes of implements used. When departures from ordinary practice are met with it is always well to learn the owner's reasons for such departures, for this may lead to the discovery of something of value in farm practice. Finally, a statement of the equipment of the farm as a whole should be obtained; also as accurate an account as possible of the annual expenses and receipts by enterprises. The blanks used by the Office of Farm Management or those used by Cornell University in making detailed farm-management surveys will be found very useful in studies of this kind, but they do not cover all the points that should be covered in making a thorough study of a successful farm for the purpose of learning from it all the lessons it has to teach. It is not possible in a farm-management survey to study each farm in such detail as the best farms justify.

MANAGERIAL EFFICIENCY.

The final chapter of a treatise on farm management may well relate to the training and the personal characteristics that contribute to managerial efficiency. The corporate principle in business has been successfully applied everywhere except in agriculture. Generally speaking, large agricultural undertakings have not been successful, principally because suitable managers have not been available. Managers have been lacking partly because the principles of farm management have not been worked out and definitely stated, and the business is too complex for the average man to become a successful manager of a large undertaking simply through experience alone. When these principles are once clearly stated, there seems to be no reason why large farms should not be even more successful, financially, than small ones. Whether it is desirable from the standpoint of national economy for the small farm to give place to the large one is a question of rural economics and does not directly concern the science of farm management. Such changes are controlled by economic forces that work in spite of our attempts to counteract them. If large agricultural undertakings could be made as successful as those of moderate size are now sometimes made, there is every reason to believe that corporate agriculture would assume an important rôle in this country, whether or not it is desirable that this should be the case.

II.—THE WORK OF THE OFFICE OF FARM MANAGEMENT.

INTRODUCTION.

Science is sometimes defined as knowledge methodically formulated and arranged in a rational system, or, to express it more briefly, classified knowledge. In Part I of this bulletin the attempt has been made to present an outline of the science of farm management, in so far as the knowledge of the principles of this science is available, and to point out the principal deficiencies in this knowledge. Farm management is a new science and the facts in this field of knowledge are as yet imperfectly known. Hence the urgency of farm-management investigations.

In organizing scientific research we may divide the branch of science under investigation into its logical subdivisions and assign investigators to each of these subdivisions, or we may organize it on the basis of methods of investigation. In the organization of the research work of the Office of Farm Management both of these methods are recognized. In the main, the subdivision of the work is based on methods of investigation, but in the various sections of the office the work is to some extent divided along the lines of the subject matter investigated. In practically all efficient organizations for scientific research this dual type of organization exists, as it does to a marked degree in the general organization of the Bureau of Plant Industry, of which the Office of Farm Management is a part.

The object of Part II of this bulletin is to present an outline of the organization and work of the Office of Farm Management, with sufficient discussion to make clear the methods of investigation followed and the purposes to be attained.

It should be stated that the Office of Farm Management developed out of the old Office of Grass and Forage-Plant Investigations. Later a new office under the latter title was organized and most of the work relating to grasses and forage plants was transferred to this new office. There were, however, a few lines of work on these crops which for various reasons were left in the Office of Farm Management. These are included in the outline below for the sake of presenting the work of the office in its entirety.

The work of the Office of Farm Management is divided into five sections, as follows:

(1) Office administration and records.
(2) Farm economics.
(3) Special farm-management studies.
(4) Farm-management field studies and demonstrations.
(5) Utilization of cacti and dry-land plants.

The work of each of these sections is discussed briefly below, but with sufficient fullness to enable the reader to gain a clear idea of the nature and purpose of the work and the methods pursued.

OFFICE ADMINISTRATION AND RECORDS.

This section is responsible for the care of the library and the various files maintained in the office, such as correspondence and field reports of the staff; for the preparation and care of photographic records; for the revision of manuscripts; and for the financial records of the office.

FARM ECONOMICS.

The subdivision of the work in the Section of Farm Economics is based partly on methods of investigation and partly on subject matter. The various types of investigation in progress are agricultural cost accounting, farm-management surveys, farm equipment, marketing farm products, agricultural credit, agricultural insurance, and history of farm management.

AGRICULTURAL COST ACCOUNTING.

Several methods, differing more or less in details, are used in cost-accounting work in the Office of Farm Management. One of these is as follows: Detailed records of all labor performed and of all transactions occurring on a considerable number of farms are received in the office and tabulated in such manner as to show the cost and income of each enterprise on the farm, as well as the general farm expenses which can not be charged to any particular enterprise. This renders it possible at the end of the year to determine the profit or loss from each enterprise, as well as of the farm as a whole.

In this work the Office of Farm Management is cooperating with the Ohio Agricultural Experiment Station, the University of Wisconsin, and the University of Missouri, the records from farms in these States being received and tabulated at the institutions mentioned and copies of the tabulations being transmitted to Washington. The records from farms located in other States are received and tabulated in the Office of Farm Management. The original records are made by the men who do the farm work, on blanks furnished by the Office of Farm Management and the cooperating institutions. Monthly summaries of the labor by enterprises are furnished the owners of the farms, and at the end of the year they are also furnished a complete summary of the records for the year, showing the cost and income for each enterprise and for the farm as a whole.

Another method differs from the foregoing in the fact that the farms furnishing the records are located in a selected locality and are visited at frequent intervals by a representative of the office whose business it is to render such service as may be necessary in keeping the records, and especially to see that the records are properly made. These groups of farms are known as cost-accounting circuits. A representative of the office devotes his whole time to the 15 to 20 farms constituting one of these circuits.

In cooperation with the New York State College of Agriculture at Cornell University the office employs a man who devotes his time to helping a number of farmers in the State of New York to develop systems of bookkeeping for their own use. These systems include cost-accounting records the tabulation of which is done by the farmer himself.

The Office of Farm Management also furnishes to several hundred farmers well distributed over the country a special form of diary, in which the farmer keeps such records as he desires and from which he makes such tabulations as he wishes. Suggestions are made to the farmer as to the records it is worth while to keep and the tabulations that would be of most service. Instructions are also given as to the details of record keeping and the making of tabulations. These books are furnished with the understanding that when they are filled (each book holds six months' records) they will be lent to the Office of Farm Management for the purpose of securing therefrom any data that may be useful in connection with the work of the office. Experience with these diaries has shown that they give much valuable data concerning the cost and income from farm enterprises and still more concerning the dates when various farm operations occur. This latter information is of special value in studying the important question of the seasonal distribution of labor on the farm. Perhaps the most important service they render the office is in showing what records farmers can be induced to keep when it is made easy for them to make the records and the use that farmers will make of such records when they are at hand. The results thus far have been very gratifying.

In the types of cost-accounting investigations just described the work has related to the whole farm. The office also conducts cost-accounting investigations relating to a single enterprise. In this work representatives of the office visit a large number of farms on which the enterprise under investigation is conducted and secure from each the data concerning every feature of the conduct of the enterprise. The data thus obtained represent either the farmer's knowledge of the details of the conduct of the enterprise or the best estimates he is able to make concerning them. The relative accuracy of information obtained in this way as compared with that obtained from detailed records kept by farmers, as well as with data obtained in ordinary experimental work, will be discussed later in these pages.

The original purpose of the cost-accounting work was to determine the cost of all classes of farm operations and the relative profitableness of the various crop and live-stock enterprises under different conditions, as well as to develop simple systems of accounting adapted to the farmer's own use. The many important lessons the results of these investigations have taught will be dealt with in other publications. Suffice it here to state that the causes of profitableness have been found quite as often in the scheme of organization of the farm as in the excellence of the methods used, if, indeed, not more often. The fact has been strongly emphasized that a proper selection of enterprises that fit well together, thus giving a satisfactory seasonal distribution of labor, and especially a system that gives full utilization of the farmer's ability, that permits the maximum wise use of power and at the same time so distributes the work as to render necessary a minimum amount of equipment, greatly reduces the cost of production per unit of product, and thus increases the profit in farming. Without such a system there is frequently little or no profit, no matter how well the work of the farm may be done. Thus it happens that while these investigations have resulted in valuable knowledge of the kind originally sought, they also furnish a vast array of facts that are of even greater value than a knowledge of the cost of doing things on the farm.

The following is a partial list of the subjects on which the records obtained in the cost-accounting work furnish data of more or less value:

Kind and number of operations required by every enterprise.

The dates when these operations may or must be performed.

The character of crew (men, horses, and machinery) required for each operation.

The amount of work these crews perform in a day, and hence the time required for each operation.

The proportion of days in a given period that are available on the average for field work, or, to state this conversely, the proportion of time lost from rain, holidays, necessary trips to town, unavoidable delays, and the like.

Cost of production and income from the various farm crops and types of live stock under a wide range of conditions.

The general farm expenses, or the "overhead charges," on the productive enterprises of the farm.

The returns per hour of labor spent on different enterprises.

The amount of use, and hence the cost per acre and per unit of product, of each item of equipment.

The rate of depreciation of farm equipment of all kinds. This is determined in two ways: (1) From the successive annual inventories and (2) from the length of time an implement lasts and the amount of work it does. This second method is, of course, possible only on farms for which records are secured for a number of years.

Length of the working day.

Time required for "chores" on farms of different sizes and types.

The relation of all phases of farm practice to crop yields.

The practicability of various crop rotations.

The conditions to which various farm enterprises are suited.

The relative profitableness of different enterprises.

Crops which compete and those which do not compete for labor at the same time of the year.

Relation of the size of farm to profit.

Relation of the type of farm organization to profit.

The cost of marketing farm products.

The rate of income on capital invested in farming.

The labor income of the farmer.

Distribution of capital between the various factors of production, such as land, buildings, fences, work stock, productive stock, implements and machinery, etc.

Cost of housing and feeding farm animals.

Cost of horse labor.

Cost of man labor.

Types of records adapted for use by the farmer.

It is clear, therefore, that these investigations cover practically the whole field of farm management. But unfortunately the securing of complete records of all the work done on a large number of farms is both tedious and costly. It would require many years and the expenditure of vast sums of money to secure all the data needed on farm-management subjects in this manner. Some of the kinds of data in the above list can be obtained in no other way, but many of them can be secured in greater quantity by cheaper methods, as will appear in the accounts of other types of investigation described in what follows.

FARM-MANAGEMENT SURVEYS.

Another important line of investigation conducted by the Section of Farm Economics is the farm-management surveys. In this work localities are selected that are believed to be representative of important agricultural regions and studies are made on every one of 500 or 600 contiguous farms, no farms being omitted from which it is possible to obtain the necessary data. These surveys are intended to reveal the actual status of the agriculture of the regions in which they are made.

Sufficient data are obtained from each farm to enable the investigator to determine the amount of capital invested, the value of all the major items of equipment, the amount and character of the farm expenses and receipts, the increase or decrease in the farm inventory for the past year, and all other facts necessary to determine the labor income of the farmer after deducting interest on the investment and wages for the unpaid labor done by members of the farmer's family other than the farmer himself.

The data obtained also permit the study of such questions as the relation of profits in farming to the education of the farmer, the relation of the age of the farmer to the percentage of tenant farming, the effect of distance from markets on the value of farm land, and numerous other questions of importance to agriculture in general.

Some very important results have been obtained in studies of this kind and some time-honored opinions on matters of importance have been shown to be erroneous. Detailed results of these surveys are published from time to time in the series of bulletins issued by the Bureau of Plant Industry, and it is therefore unnecessary to discuss these results at length here.

A word as to the accuracy of the results obtained in these surveys. The data obtained from the farmers represent their knowledge, and in cases where they do not have definite knowledge, their estimates as to the details of the farm business during the year just past. It sometimes happens that it is possible to test the accuracy of the results thus obtained. This was the case in one detail of a recent survey made by this office in one of the New England States.

Among the several hundred farms included in the survey were 135 that sold milk to creameries. Each of these farmers was asked to give as accurate an estimate as possible of the amount of money he had received for this milk. After the survey was partially finished it occurred to the investigator that it would be possible to secure a check on the accuracy of these estimates by obtaining the actual figures from the creameries themselves. It was decided also to test in a similar manner the farmers' estimates of the quantity of milk each had sold to the creamery. The estimates as to quantity of milk sold were then obtained from the 79 farms visited after the decision had been reached to make this test. These farmers did not as a rule weigh their own milk and were not accustomed to dealing with weights as they were with sums of money; it was to be expected, therefore, that the estimates of quantity of milk sold would be less accurate than those of money received, and this was the case, as will be shown below. After obtaining the estimates from the farmers, the actual figures, both for weights of milk sold and for money received, were secured from the creameries that had purchased the milk.

Estimated pounds of milk sold (79 farms)	3, 518, 816
Actual pounds of milk sold (79 farms)	3, 487, 320
Difference	31, 496
Estimated value of milk sold (135 farms)	$106, 163. 00
Actual value of milk sold (135 farms)	106, 155. 50
Difference	7. 50

It is seen that the error in the quantity of milk sold is a little less than 1 per cent of the whole. At the same time the individual estimates of pounds of milk sold were in error by amounts ranging from 40 per cent above to 36 per cent below the correct figures. In the total these errors tended to counterbalance each other, so that the sum of the estimates was quite accurate. In the estimates of money, in terms of which the farmer is accustomed to reckon, the error in the total is less than one-hundredth of 1 per cent. These instances will serve to show something of the measure of accuracy attainable in the results of the farm-management surveys. There is, however, another source of error in such data that is more important. The data obtained apply only to the season in which the survey is made; the results therefore may not represent average conditions in the regions studied. The only way of obviating this difficulty is to repeat the work for several seasons in the same region, and this will be done in all cases where there is reason to believe that the conditions are abnormal during the year in which the first survey is made in the locality.

The relative accuracy of results obtained by gathering data from experience and from data obtained in plat experiments deserves further notice here, in view of the fact that the type of investigation represented by the study of farm practice has not been much used hitherto and its value is not yet fully appreciated by students of agricultural problems. It is unnecessary to dwell on the inherent inaccuracies of plat experiments, especially those due to unavoidable causes, such as the variation of soil in adjacent plats and the variations in seasons which affect different plats differently. In judging the accuracy of final results where these results represent averages of a number of separate observations or measurements two questions are to be considered, i. e., the number of observations involved in each average and the accuracy with which the original observations or measurements were made.

It is a well-established mathematical principle that, other things being equal, the reliability of an average increases as the square root of the number of observations included in the average. From this standpoint the method of investigation by the study of farm practice has a very distinct advantage over that of plat experiments on account of the vastly larger amount of data that can be obtained with a given expenditure of time, energy, and money, assuming, of course, that the problem is one that has actually been worked out in farm experience, whether those who have worked it out are aware of the fact or not.

The relation of the accuracy of the final average to the accuracy of the original observations is a matter that is often overlooked in experimental work, and consequently a great deal of effort is wasted by attempting to secure great accuracy in one of the controlling factors in the case when the results are rendered inaccurate by inaccuracy in others. A chain is not made stronger by strengthening the link which is already strongest. If great variation in the yield of a crop, for instance, is due to irregularities of the soil and to variations in seasons which affect different plats differently, then no great increase in the degree of accuracy in the final result is obtained by using extreme care in measuring areas of plats and yield per acre. This point is illustrated in figure 1.

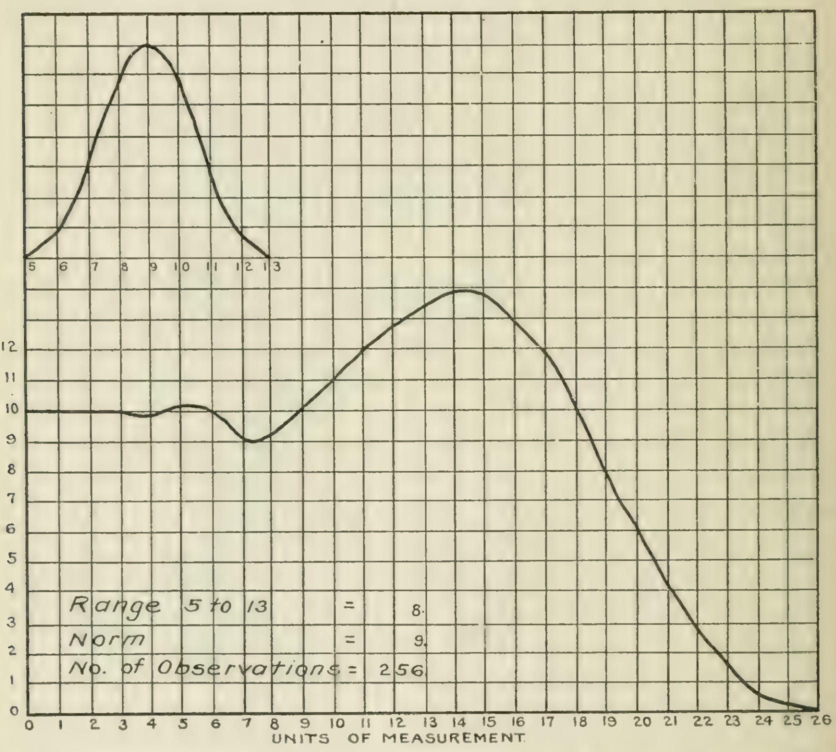

FIG. 1.—Diagram showing the relation of the accuracy of an average to the accuracy of the numbers averaged.

The upper curve in this diagram is a frequency curve for a series of 256 observations of a variable quantity whose range of variation is from 5 to 13 on the scale adopted in the diagram. This degree of variation is comparable to that of the yield of a crop in plat experiments covering a series of years or a series of plats side by side the same year. The true average of the 256 observations in this case is 9. If instead of the true values of the observations, made originally, say, to the second decimal place, we take in each case the nearest unit, the average is still 9, as shown in the lower curve of the diagram. In this lower curve the figures at the bottom (abscissas) represent the units of measurement used in making the observations to be averaged, and the ordinates of the lower curve show the corresponding averages. It is seen that the inaccuracies of the averages are too small to represent in the diagram until the unit in which the measures are made reaches the magnitude of three divisions of the scale, which is three-eighths of the whole range of variation of the variable. In other words, we make no essential gain in accuracy of the final average by making the original observations more accurately than to use a unit equal to three-eighths of the range of variation.

It should be stated that this conclusion does not apply to all kinds of averages, but it does apply to those cases in which the observations form a frequency curve of approximately the form shown in the diagram (upper curve). This means that in determining the average yield of a crop that varies from year to year by as much as 24 bushels per acre, when the number of experiments is large, we make no appreciable gain in accuracy by using a unit of measurement smaller than 9 bushels. Thus, if any yield between 4½ and 13½ is recorded as 9, yields from 13½ to 22½ as 18, from 22½ to 31½ as 27, and so on, the final average, if the number of yields in the average is considerable, will be approximately as accurate as if the yields had been determined to the hundredth part of a pound per acre. In other words, when the number of observations is large, a series of guesses by those who can make reasonably good guesses gives a result about as reliable as the most accurate measurements when the quantity to be measured or considered is highly variable. On account of the importance of this matter and the fact that these principles are not generally understood except by students of the theory of probabilities, further illustration of them is given below.

In the American Naturalist for April, 1909, Dr. R. Pearl, of the Maine Agricultural Experiment Station, shows that in the measurement of the length of 450 hen's eggs to the nearest millimeter only the average of these measurements is correct to the nearest hundredth of a millimeter; i. e., the average was more accurate than the measurements on which it was based.

Again, the mean annual rainfall at Philadelphia for a period of 66 years, from 1826 to 1891, inclusive, was 43.2 inches, the measurements being made to the nearest tenth of an inch. At the end of the first 10 years of these observations the annual mean was 40.4 inches. There is no doubt that the mean for 66 years is more nearly the true value of the mean than that for 10 years. Taking the 66-year mean as the true value, the 10-year mean is in error to the extent of 2.8 inches. If, now, instead of the true value of the rainfall each year we take the nearest 10 inches, so that, for instance, any rainfall between 25 and 35 inches is recorded as 30 inches, the average thus obtained for the 66 years is 42.9 inches, an error of less than 1 per cent of the true average, while the 10-year average from accurate measurements is in error over 6 per cent. Not only that, but the 66-year average when precipitation is recorded to the nearest multiple of 10 inches agrees more closely with the 66-year average made from records reading to the tenth of an inch than does the average of any of the 10-year periods during the first 60 years of this time, even when the data on which the 10-year averages are computed is highly accurate. This shows that in securing the average value of a variable quantity the number of observations is more important than precision of measurement.

Enough has been said to show that data collected from farm experience, if sufficiently abundant—and they can easily be made so—give results even more dependable than the results of the ordinary plat experimental work. Data so obtained compare favorably with the best plat experiments when the subject under investigation is adapted to this method of investigation.

Farm-practice results secured by this method relate to real farm problems, which can not always be said of experiments planned in the experimenter's office.

FARM EQUIPMENT.

While the cost-accounting work was primarily intended to determine the cost and profit of farm operations, we have seen that incidentally it furnishes much valuable information relating to practically every phase of farm management. The farm-management surveys, while not covering so wide a range of subjects, still cover a good part of the field. These two divisions of the work represent different methods of investigation rather than different fields of investigation. On the other hand, the investigations relating to farm equipment represent one of the subdivisions of the science of farm management as outlined in Part I of this bulletin. The methods used in the investigation of equipment problems are closely similar to those used in the farm-management surveys, though they are more detailed than the latter, much more time being given to the equipment of a given farm or enterprise. The data regarding equipment are in the main obtained by personal visits to the farms studied, careful inventories of the various items of equipment being made.

The factors which determine equipment are, in many instances, numerous, variable, and complex, for which reason the necessary or justifiable equipment for given conditions can, in many cases, be ascertained only through experience. At the same time such wide variation exists in practice that the true resultant of the forces which control equipment can only be found by considering a large number of cases, for it is necessary to have large numbers of observations in order to secure reliable averages. Hence, methods that are more rapid and less expensive than those used in the cost-accounting work are better adapted to the solution of the main problems of farm equipment. The method already outlined (see p. 29) for ascertaining the proper or permissible cost of the farm dwelling illustrates well the general method of attacking the more complex problems relating to farm equipment. We can not solve such a problem simply by determining the number of individuals to be housed and the number of cubic feet of inclosed space each requires, for people differ in taste both as to the amount of space needed for each individual and as to the appearance of the inclosed space, viewed either interiorly or exteriorly. We can, however, ascertain how much it is safe financially for the farmer to expend in inclosing this space. But the forces that determine this limit of safety are subtle ones that can not be measured directly; we can only measure their general resultant by taking the averages of large numbers of cases.

Similarly complex and subtle forces determine many other features of farm equipment, though in many cases it is possible to determine equipment needs more directly from the definite relations existing between character of equipment and the nature of the thing to be accomplished. Thus, when a system of cropping on a farm is once determined, it is possible, in many cases at least, to state at once certain items of equipment that will be necessary, or at least highly desirable, in carrying out this system. But if a farm has 20 dairy cows, 10 head of young stock, 5 work horses, and 40 ewes, it is not so clear just what buildings this complement of stock necessitates or what these buildings should cost. It is possible, by taking account of the stock to be sheltered and the amount of feed for them that must be stored, to determine quite accurately the amount and character of the inclosed space needed; but how much money the farmer would be justified in putting into these structures must be determined in another way. Many farmers would settle such a question by building the cheapest structures that would answer the purpose, even inadequately. Others would desire more adequate, and even ornate, structures. An actual census of the farm buildings on farms having the above complement of stock would undoubtedly show a variation of 200 or 300 per cent or more in the cost of the buildings in use. In building a cow barn, for instance, it is possible to secure shelter for the cows and their feed at a cost per head of less than $2, though perhaps not adequate shelter. Yet cow barns exist in this country that cost over $2,000 per head for the animals sheltered. What sum is the farmer justified in putting into such a structure? This is a question that can be answered only by a careful study on a large number of successful dairy farms. The fact that a farm is successful is evidence that in such matters it has not far transgressed the limits of prudence on the one hand or of adequacy on the other. The study of actual practice on a large number of successful farms is thus the best means of arriving at the solution of many of the problems relating to farm equipment.

A few farmers are able to determine quite accurately their needs in the way of equipment, but the vast majority of them make more or less serious mistakes. Especially is this likely to occur when the farmer changes his type of farming and takes up one or more enterprises with the equipment of which he is not familiar. A great deal of money is wasted in equipment that is not needed or is not suited to the purpose it is intended to serve. On the other hand, many farmers obtain poor results for lack of suitable equipment, and this is not always because they can not afford to buy the needed equipment, but because they do not know what they need. Because of these facts the Office of Farm Management has undertaken to ascertain what is adequate and satisfactory equipment, so far as this is possible, for the conduct of farms of all sizes and types in all sections of the country. The mere fact that the actual equipment in use for accomplishing the same thing varies widely on different farms does not present an insurmountable obstacle in the investigation of this question, though it does make the problem difficult. It is, however, rendered much more complicated by the fact that changes in the type of farming are continually going on in nearly all sections of the country. But the fact that these changes are going on makes the work all the more urgent.

The following is a brief outline of the more important subjects under investigation relating to farm equipment:

Distribution of capital between the various factors of production: The relative amount of capital invested in land, buildings, work animals and other stock, implements and machinery, supplies, and ready cash for current expenses on farms of different sizes and types in different climatic regions.

The farm dwelling: Its cost, peculiarities of farm dwelling as contrasted with city dwellings, interior arrangement, design, and construction.

Other farm buildings: Amount and character of inclosed space needed under given conditions; space units per animal; the arrangement of the inclosed space in relation to convenience and economy; the location of buildings with reference to each other and to the farm as a whole; farm practice in design and construction of farm buildings and the principles involved in the same; the cost of buildings under all conditions; the cost of keeping buildings of different types in repair; and the rate of depreciation of buildings.

Farm fences: Conditions requiring or justifying fences; relation of the layout of the farm to economy in fencing; types of fences and their uses; the cost of fences of different types; the cost of materials for all kinds of fences; the amount of labor required in constructing fences; the cost of keeping fences in repair; and the rate of depreciation of farm fences.

Water supply and sewage disposal on the farm: Types of equipment and cost and practicability of the same.

Systems of heating and lighting farm buildings and the cost of installing and operating the same.

Equipment of farms of a particular type.

Relation of the size of the farm to the character, especially the size, of the equipment.

Equipment for particular enterprises.

General farm equipment: Equipment that can not be charged directly to any one of the productive enterprises of the farm. Equipment of this kind accounts for part of the general farm, or "overhead," expenses, which must be apportioned between the productive enterprises in determining the profit of these enterprises.

Minor items of equipment: This includes those small items that are never, or at least seldom, enumerated separately in the farm inventory, but are lumped together under the general title "small tools, etc." One important study of this kind has already been published. (See Circular 44, Bureau of Plant Industry, entitled "Minor Articles of Farm Equipment.")

Equipment for particular operations: This includes a study of the wide variation in farm practice in performing the same work and of the causes underlying this variation; the cost of a given operation when performed with different equipment; and a complete study of crew work of all kinds, including the number of men and horses in the crew, and the number, kinds, and sizes of implements or machines used by the crew, as well as the part each member of the crew plays in the operation.

Duty of machinery: This is a study of the amount of work a machine or implement does, or should do, in a given time, such as an hour, a day, or a working season.

Standards of farm labor: A study of the amount of labor that may fairly be expected of a farm laborer under all conditions and in all kinds of farm work. Data of this kind are of enormous value in the management of hired labor, as well as in planning in advance a season's work or in making out a working plan for a farm.

The proportion of time available at different seasons of the year for work of different kinds, especially for field work.

The amount of labor and the number of work animals needed on a given farm at different seasons of the year.

Equipment charges: The rate of depreciation of farm equipment of all kinds; the cost of repairs; the cost of housing implements and machinery; the rate of interest on money invested in equipment of different kinds; and the amount of annual use of equipment and its bearing on the equipment cost of farm operations.

The conditions, especially the amount of use, that justify the purchase of a given item of equipment; conditions which make hiring more desirable than the purchase of equipment.

Advantages and disadvantages of joint ownership of the more expensive machines and implements.

Use of mechanical power instead of horse power on the farm. (See Bulletin 170, Bureau of Plant Industry, entitled "Traction Plowing.") Attention is given to types and sizes of tractors in use; conditions to which the various types are best adapted; conditions which justify the purchase of a tractor; the original cost, the cost of repairs, and the rate of depreciation of farm tractors; the cost of operation and the crews and supplies required; the amount of work done per day and per season; and the cost per unit of work done.

The Office of Farm Management receives numerous inquiries as to the relative merits of different makes of implements designed for the same work. These are problems in farm engineering and are not strictly farm-management problems. To answer such inquiries would involve long and painstaking research, requiring extensive laboratory equipment, necessitating exhaustive inquiry into methods of mechanical design, construction and efficiency, the strength and adaptability of materials, etc., all of which are lines of work requiring a different education and training and a different point of view from that of farm management. It would also involve complications with the patent laws if undertaken under Government auspices. This fact and the further fact that such investigations might involve conflicts with private inventors and manufacturers who are spending much time and money in such investigations have hitherto operated to prevent the appropriation of public funds for the study of such problems. But the opposition of manufacturers to investigations of this character has largely disappeared, and would entirely disappear if such modifications of the patent laws could be devised as would both protect the inventor and at the same time give every manufacturer the privilege, under proper supervision and control in the interest of the inventor, of using any patented device that would improve the articles manufactured by each. Even at the present time manufacturers would quite generally welcome public engineering laboratories and test stations that would furnish data as to the mechanical types that would be best adapted to farm needs in the various agricultural sections of the country. Such investigations would save both the farmer and the manufacturer millions of dollars now wasted in poorly designed and constructed machinery.

HISTORY OF FARM MANAGEMENT.

Ancient and medieval literature regarding farm management, while by no means extensive, is yet sufficient to enable the careful student to gain a fair idea of economic conditions in agriculture at most stages in the history of European nations. This is especially true of Italian agriculture during the days of the Cæsars and of English agriculture practically from the time of the Roman occupation, near the beginning of the Christian era. In the period during which the Romans produced their most enduring literature it was fashionable for scholarly men to own country estates, and no small amount of literature is extant relating to the management of these estates. It has always been fashionable for the English nobility to own land and to farm it. Even in the early centuries of the Christian era it was the custom on country estates in England to keep fairly complete records of farming operations. A careful study of this old literature is being made in order to summarize for publication such of it as will interest farmers.

The three subjects following belong to rural economics rather than to farm management, but are investigated in this office on account of their intimate relation to the subject of farm management, as well as for administrative reasons.

MARKETING FARM PRODUCTS.

A study is made of the methods used in different parts of the country in preparing farm products for market, especially those that go to the ultimate consumer in the form in which they leave the farm, with special reference to the effect these methods have on the prices received; methods used in transporting farm products, especially perishable products, to distant markets, and the relation of these methods to market values; methods of organizing and conducting cooperative marketing associations; the effect these associations have on the net returns received by the farmer; the distribution of enterprises with relation to the market centers; and finally the difference between prices received by the farmer and those paid by the consumer and the reasons for this difference.

AGRICULTURAL CREDIT.

An investigation is made of the sources of available credit for the farmer, the conditions under which the farmer may obtain credit for financing his operations, and the rates of interest on farm loans. It also includes a study of the details of organization and operation of agricultural loan associations, both in America and in Europe, with special reference to those features which adapt these organizations to American conditions.

AGRICULTURAL INSURANCE.

This is a study of forms of insurance most patronized by farmers, and especially of farmers' mutual insurance societies, their organization and conduct, and the rates of insurance paid. Attention is given to life, fire, crop, live-stock, and all other forms of insurance, but especially to those forms conducted by farmers' mutual organizations.

SPECIAL FARM-MANAGEMENT STUDIES.

In conducting farm-management field studies the country may be divided into geographic sections and men assigned to each of these sections for the purpose of studying the farm-management problems that present themselves, as is done in the Office of Farm Management in the case of the broader and more fundamental problems, or men may be assigned to a particular problem without restriction as to the territory covered, being guided in this matter by the geography of the problem itself. In this office this latter method is pursued in the case of problems which, however important they may be, are not of sufficient magnitude to justify assigning more than one or two men to their investigation or which are only distantly related to the major problems of farm management. These problems are here brought together under the above heading. Some of them are inherited from the old Office of Grass and Forage-Plant Investigations, out of which the Office of Farm Management developed, and were left in this office when the new Office of Forage-Crop Investigations was organized, either because of the personal interest of certain members of the staff in the problems in question, because they involved certain phases of farm management or because there was no other office in the Bureau of Plant Industry that was directly interested in them. Some of them, however, relate strictly to fundamental problems in farm management. These special problems follow.

TENANT FARMING.

The lack of further opportunity for taking up desirable public lands in our Western States and the consequent general rise in the price of farm lands practically all over the country has resulted in an increase in tenant farming, especially in those sections where land values have risen to the point at which it is exceedingly difficult for the purchaser of a farm to meet both living expenses and interest on his indebtedness and also make payments on the principal. It can hardly be doubted that tenant farming will further increase in this country and that ultimately the land will largely be owned by the wealthier classes and be farmed by tenants with moderate capital.

It is to be hoped that the work which the National Government and the States are now doing for the benefit of the farming classes will ultimately enable a larger percentage of farmers to own the land they farm; but the problems relating to tenant farming are not only important at the present time, but are likely to become more so. Two phases of the subject are receiving special attention in this office at the present time. One of these relates to the amount of working capital required to conduct a farm properly, especially with a view to maintaining the fertility of the soil, and the possibility of inducing the landlord to furnish this capital where the tenant is unable to do so. The other relates to the details of the contract between landlord and tenant. Both the cost-accounting work and the farm-management surveys, as well as the farm-equipment studies, furnish much valuable information on the first of these two problems, but it is also receiving direct study as a separate problem by a careful study, especially of those tenant farms that are being conducted in a satisfactory manner.

Sufficient discussion has already been given the problem of the contract between landlord and tenant (pp. 31–32) to give the reader an idea of the phases of the subject that are under investigation. Investigations thus far conducted indicate that the central problem in the contract is the share of the farm income that is to go as reward for labor and the share that shall constitute the income on capital invested. On certain large estates that have for many years been let to tenants and on which the securing of satisfactory tenants is a major problem this problem of labor's share of the farm income has been quite definitely solved, that is, it has been worked out what proportion of the income must go to labor in order to secure and hold desirable tenants. There are many such estates in this country, one of them consisting of 200,000 acres of as good land as the country affords. The results of these investigations will be given in separate publications. (See Farmers' Bulletin 437, entitled "A System of Tenant Farming and Its Results.")

RELATION OF GEOGRAPHIC FACTORS TO THE DISTRIBUTION OF FARM ENTERPRISES.

Types of farming and farm enterprises generally find their proper place in the agriculture of any country. But the process, unaided by science, is slow and exceedingly expensive. Millions of dollars have been wasted by the farmers of this country in finding out what crops, types of live stock, and farm-factory processes are adapted to each of the various agricultural sections of the country. Very little serious attempt has been made to ascertain what are the real limiting factors in the distribution of these enterprises. The Office of Farm Management is undertaking a general study of the relations existing between the distribution of enterprises and such geographic factors as the amount of rainfall, the seasonal distribution of rainfall, the length of the growing season, the dates of the last frost in the spring and the first frost in the fall, and the topography, elevation, latitude, geological formation, and character of the soil.

CLEARING AND UTILIZATION OF LOGGED-OFF LAND.

There are yet many millions of acres of land to be cleared for farming. This is mostly land from which all the merchantable timber has been cut; hence the designation "logged-off land." Much of this land has lain unused for many years because of the expense of removing the stumps from the ground. Now that free land ready for the plow is practically a thing of the past, these logged-off lands assume an importance they did not possess a few years ago.

The study of the problems of clearing and utilizing logged-off land, though not strictly a subject for farm-management investigations, has been carried on by the Office of Farm Management for reasons already suggested, and this office is investigating the methods in use in the various sections of the country where these lands are being put into cultivation, as well as studying problems connected with the improvement of these methods. (See Bulletin 239, Bureau of Plant Industry, entitled "Cost and Methods of Clearing Land in Western Washington.")

RELATION OF FARM PRACTICE TO CROP YIELDS.

Probably more effort has been given to the attempt to learn how to increase crop yields than to any other single problem in agriculture. While much has been learned, we are yet far from having a satisfactory understanding of this most important subject. All over this country, at least in the older settled sections, there are farms on which definite systems of farming have been followed for a sufficient length of time to permit the system to have produced whatever effect it will on the fertility of the soil. The Office of Farm Management is engaged in gathering up careful records of these systems, especially those that give satisfactory crop yields, with a view to studying, by means of comparison of the different systems and the resulting yields, especially those under similar climatic and soil conditions, the effect different elements in the systems have on the yield of crops.

FARM MANAGEMENT IN SUGAR-BEET CULTURE.

The different viewpoints of farm management and agronomy with reference to a crop were fully discussed on page 14. In the case of sugar beets the agronomist is concerned with the methods to be used in order to produce the greatest tonnage of available sugar per acre. The investigator in farm management is concerned with the equipment required for the production of beets, with the labor necessary and the distribution of this labor during the season, and also with the relative profitableness of this crop as compared with others to which the farmer might devote his land; in short, with the economic conditions which render sugar beets a desirable farm enterprise. Studies of this character are in progress, in cooperation with the Office of Sugar-Plant Investigations.

Exactly similar studies are being made of all the leading farm crops of the country, but for the most part these studies are made incidentally in connection with the farm-management field studies to be described later in this bulletin.

WEEDS AND TILLAGE IN RELATION TO FARM PRACTICE.

Farm practice in weed control and in the matter of tillage is more closely related to the work of the Office of Farm Management than to that of any other office in the Bureau of Plant Industry, for which reason this work is conducted in this office. It is a line of work which developed out of the attempt to find a method of eradicating Johnson grass, which attempt was entirely successful (see Farmer's Bulletin 279, entitled "A Method of Eradicating Johnson Grass") and thus represents an inheritance from the old Office of Grass and Forage-Plant Investigations. While both lines of work (weed control and tillage) are studied mainly from the standpoint of farm practice, some experimental work is conducted on both of them.

The distinctive method of weed investigation developed in this office consists of a detailed study of each weed for the purpose of ascertaining its complete life history, especially the methods of propagation possible to it. The season of the year at which seeds, rootstocks, bulbs, and other parts capable of originating new plants are formed, as well as the stage of growth the mother plant must reach in order to be able to form these propagating parts, and the length of life of any part of the plant capable of originating new individuals are accurately determined. In the case of most perennial weeds thus far investigated this knowledge has pointed to certain easy methods of eradication. Thus, in the case of Johnson grass, the weedy character of which arises from the freedom with which it produces rootstocks, the rootstocks do not begin to form until about the time the plant has reached the blossoming stage. If the plant is cut back, as in mowing hay, before the rootstocks are formed, the energies of the plant are then directed toward throwing up new aerial growth instead of the development of rootstocks. If the plants are kept cut back during the whole season rootstocks do not develop until late in the season, and then only feebly. It is only these newly formed rootstocks and the crowns of the old plants (and, of course, the seeds) that will give rise to new growth the next year. A single very shallow plowing late in the season, after the plants have been cut back so as not to allow them to produce blooms during the summer and before the rootstocks have made more than the merest start to form, thus completely destroys the plant and leaves no means of propagation for the following season. By taking advantage of these facts clean crops of cotton have been grown on land from which Johnson-grass hay had been cut the previous season. Similar studies have been made of wild onion and of quack grass, and easy methods for the eradication of both of these pests have resulted (see Farmer's Bulletin 464, entitled "The Eradication of Quack-Grass," and Circular (Document 416), Bureau of Plant Industry, entitled "The Wild Onion").

Particular attention is now being given to the relation of weeds to the various crop rotations practiced in different sections of the country.

Investigations of farm practice in the methods of tillage in all parts of the country are in progress, the object being to ascertain what are the fundamental causes of present practices, as well as the bearing of economic conditions on methods in use in different sections. Is the 15-inch sweep used for cultivating cotton in so many parts of the South due to the meager amount of power necessary on a one-man cotton farm or is this implement actually the best type of implement to accomplish the purpose for which it is used? Some recent results of tillage experiments conducted in this office seem to indicate that implements of the type (but not necessarily of the size) of the sweep are, in fact, the logical implements to use for tillage of crops like cotton and corn. These investigations point very strongly to the conclusion that the object of cultivation on soils that are well filled with growing plant roots is not to create a mulch but to kill weeds. If this is true, the sweep, or scrape, may be the best implement now available for the tillage of growing crops.

The methods used and the results obtained in these tillage experiments are given in detail in another publication (see Bulletin 257, Bureau of Plant Industry, entitled "The Weed Factor in the Cultivation of Corn").

FARM-MANAGEMENT FEATURES OF HAYMAKING AND THE UTILIZATION OF THE HAY CROP.

The farm-management features of haymaking relate to the amount and kind of labor required and the season of the year when this work must be done. They also include the cost of producing hay and the best manner of utilizing the crop as a source of revenue on the farm. One other feature of haymaking that is receiving attention is methods and cost of curing hay by artificial heat. The labor distribution on the hay crop is, of course, studied from the standpoint of farm practice. The work on artificial curing is experimental. This work is slow and expensive, and it will be some years before positive results can be announced. (See Farmers' Bulletin 508, entitled "Market Hay.")

PASTURES AND CROPPING SYSTEMS FOR LIVE STOCK.

The study of problems relating to the maintenance of pastures and the place of pastures in the economy of the farm was begun in this office before it was converted into the Office of Farm Management, and certain phases of this study are still continued in cooperation with the new Office of Forage-Crop Investigations. A study of the practice of those stock farms which maintain pastures in productive condition is being made. Problems relating to the renovation of worn-out pastures are under investigation in cooperation with the office last mentioned. Special attention is being paid to the cropping systems used on successful stock farms in all sections of the country.

FARM-MANAGEMENT FIELD STUDIES AND DEMONSTRATIONS.

RELATION TO THE FARMERS' COOPERATIVE DEMONSTRATION WORK.

In the cotton-producing States, including Virginia, North Carolina, South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, and Texas, the work of the Section of Farm-Management Field Studies and Demonstrations of the Office of Farm Management is confined to the investigation by the study of farm practice of problems relating to farm organization and farm operation, all the demonstration work in these States being conducted by the Farmers' Cooperative Demonstration Work, which constitutes a separate office in the Bureau of Plant Industry. Although this investigational work is conducted in close cooperation with the Farmers' Cooperative Demonstration Work, the two are administered independently. In other States this section of the Office of Farm Management conducts both investigations and demonstration work, and no effort is made to keep the two types of work separate, the same staff conducting both.

ORGANIZATION.

In the administration of the work of the Section of Farm-Management Field Studies and Demonstrations of the Office of Farm Management the country is grouped into three divisions, as follows: The North Atlantic and North-Central States, the South Atlantic and South-Central States, and the Western States. The second of these divisions includes the cotton States, in which, as above stated, the Office of Farm Management does no demonstration work, and, in addition, includes the States of Delaware, Maryland, West Virginia, and Kentucky, in which the office conducts both investigations and demonstrations. It is probable that as the demonstration work of the office grows the first of the divisions specified will be separated into two. A division leader has charge of the work in each of the foregoing groups of States. Another assistant to the section leader has charge of the boys' and girls' agricultural club work in all the States except those in which the Farmers' Cooperative Demonstration Work is organized. In these States the latter office has charge of this work.

Each of the geographic divisions mentioned is subdivided into groups of a few States each, and the division leader has an assistant in each of these groups of States. These assistants are known as district leaders. They devote their time mainly to the investigation of farm practice, but assist in the supervision of demonstration work. In the cotton States their whole time is devoted to investigational work. The investigational work conducted personally by the leader of this section of the office, by the division leaders, and by the district leaders is not conducted in direct cooperation with State agencies.

But all demonstration work conducted by the office and such investigations as are conducted by those in local charge of the demonstration work are conducted in cooperation with State agencies in the manner outlined below wherever it is possible to arrange for such cooperation.

The recent development of the demonstration work conducted by this section of the Office of Farm Management has made necessary an extension of the foregoing plan of organization in order to provide adequate supervision of the demonstration work and to facilitate cooperation in this work with State agencies. The general plan for this extension of the organization of this section of the office is outlined below. This plan is modified as occasion requires to suit the exigencies of the institutions in cooperation with which the work is done.

A State leader who has general charge of farm-management field studies and demonstrations in the State is employed jointly by the United States Department of Agriculture and the cooperating institution, the salary and expenses of this man being paid jointly by the two parties to the cooperation. It sometimes happens that when the work is first instituted in a State only one of the cooperating institutions is provided with the necessary funds. In such cases the institution having the funds bears the expense until such time as the other can secure funds for this purpose. At the inception of this work in a State it also sometimes happens that the number of men employed as county demonstrators is small and the State man has been permitted to work entirely for the State institution for a portion of the year, usually devoting his time to the teaching of farm-management subjects, the entire salary of the man during such employment being paid by the State institution. But this arrangement is in all cases looked upon as temporary, for with the full development of the investigational and demonstration work the entire time of the State man will be required for its supervision and conduct.

The plan of organization of the work under the direction of the State leader is as follows: Local agents are stationed in the various counties of the State and are made responsible for the conduct of demonstration work and the investigation of local problems in the county. The salaries and expenses of these local men are borne jointly by the Department of Agriculture, the State, and the county, assisted by organizations or individuals who may be interested in the work. In cases where the State or county can not provide funds for this purpose the expenses are borne jointly by the department and private organizations or individuals. In the past the local funds have been provided partly by the county and partly by chambers of commerce, farmers' organizations, banks, railroads, and individuals who are interested in the development and improvement of the local agriculture. In several States the legislatures have empowered the county authorities to appropriate funds for this work.

The counties in which local agents are employed are grouped together into districts of about 10 counties each, with a supervisor at the head of each. The county men report to and work under the direction of these supervisors, who in turn are under the direction of and report to the State leader. Where State or local funds are available for the purpose, the salaries and expenses of the supervisors are paid jointly from these State or local funds and funds from the Department of Agriculture; otherwise the department provides the funds.

Copies of all results obtained in the investigation of farm practice, as well as all records of demonstration work done and results obtained by the State leader and the staff working under his direction, are furnished both to the cooperating State institution and to the Department of Agriculture. The character of both the investigational work and the demonstration work to be done in any case is agreed upon by the parties to the cooperation, and the State man in charge works under the joint direction of a designated representative of the cooperating State institution and the division leader in the Office of Farm Management. The cooperating institution furnishes office facilities to the State man, and similar facilities are furnished to the county agents by the counties or by local organizations or individuals. The local agents devote most of their time to demonstration work and comparatively little time to investigational work. The time of the supervisors is more largely devoted to field studies. State men and the division and district leaders devote their time to the investigation of farm-management problems by the study of actual conditions existing on the farms in their respective territories and to the supervision of the demonstration work.

OBJECTS.

The objects to be accomplished by the work of the Section of Farm-Management Field Studies and Demonstrations of the Office of Farm Management may be briefly stated as follows:

(1) To carry to the farmer the results of scientific research in his behalf, as well as the results of the experience of other farmers, and to aid the farmer in applying these results in his work.

(2) To reorganize and redirect the agriculture of the various sections of the country in such a way as to secure on each farm not only enterprises that are profitable in themselves, each being so conducted as to bring maximum net returns, but also to secure a system of enterprises that will permit the largest economical use of power, capital, and labor possible under the conditions, and which will give as nearly as possible an even distribution of labor and a full utilization of equipment throughout the year.

In this section of the office the results of the investigations of other sections of the office, as well as of other offices of the Bureau of Plant Industry, find their final application on the farm through the work of local agents engaged in extension work.

PROBLEMS AND METHODS.

The investigations of the Office of Farm Management have shown that the principal factors of profitableness in farming are as follows:

(1) Character of the enterprises constituting the basis of the farm business.

(2) Amount of power used per individual employed.

(3) Amount of capital employed.

(4) Distribution of capital between the factors of production, such as land and buildings, work stock and other animals, implements and machinery, etc.

(5) Amount of labor (profitably) employed.

(6) Seasonal distribution of labor and maximum utilization of minimum equipment.

(7) Systems of management of the individual enterprises.

(8) Methods of marketing.

The selection of enterprises that are to constitute the basis of the farm business has been considered quite fully in the first part of this bulletin. (See pp. 9–14.) A summary of the factors which determine what enterprises are adapted to given conditions is given on page 13. A great deal depends upon the wisdom with which the selection of enterprises is made. The study of this question is a very important part of the work of those connected with this section of the office. This is especially true of the work of the county agents; the supervisors who have charge of groups of counties; and especially of the district leaders, who have charge of a group of States. Very frequently it will occur that some crop or some type of live-stock farming is well adapted to a general region but not well developed in that region. In such cases it is an important part of the work of this section of the office to develop this enterprise. (See "Types of Farming in the United States," Yearbook U. S. Dept. of Agriculture for 1908.)

In doing this, great circumspection must be used. In the first place, it must be certain that the enterprise is well adapted to local conditions. Another very important point which must be considered is the probable effect upon the markets of a large increase in any enterprise. As was stated earlier in this bulletin, those enterprises which represent the principal crops and types of live-stock farming of the country may usually be largely increased in a given limited territory without disturbing the supply and demand to any noticeable degree; but enterprises which are themselves only a small part of the agriculture of the country, such as beans, hops, and even potatoes, which so far as soil and climatic conditions are concerned are enormously less developed than they might be in this country, should not be encouraged to such an extent as to threaten great overproduction. In regions that are more or less segregated from the general markets this applies even to enterprises that are largely developed in the country as a whole. In such regions the district leaders especially should make it a part of their duty to determine what the possibilities are in the way of marketing a largely increased product of any kind before the effort is made to increase production to any considerable extent. District leaders should read carefully what is said on pages 9 to 14 on this subject.

In determining the enterprises that are to be encouraged in a given region careful attention should be paid to the relation of crops to soil types. Supervisors and county agents especially should give attention to this matter. Very frequently it will be found that one variety, say, of corn is adapted to rich bottom land while another variety in the same general region is adapted to the thinner uplands. In general, attention should be given to the character of the local varieties that are grown and the relation of these varieties to the various types of soil occurring in the region.

In many parts of the country efforts are being made to introduce new crops. For instance, alfalfa is being tried by farmers all over the country. Soy beans are also under experiment very generally on farms in the eastern part of the United States. In recommending any new crop to the farmer the soil requirements of this crop should be thoroughly understood, as well as the effect it will have upon the seasonal distribution of labor on the farm. Both soy beans and cowpeas have had some difficulty in finding a place on farms in the eastern United States because of the fact that they require a good deal of labor at the same time as corn, and hence interfere to some extent with the seasonal distribution of labor. All these questions should be taken into account in recommending any new enterprise to the farmer.

The relation of the amount of power employed per individual to profit in farming has been quite fully discussed in the comparison of one-man cotton farming with one-man wheat farming. (See pp. 17–23.) In the first of these types of farming the man utilizes only one work animal, and this one not to its full capacity. In the other, one man usually uses five horses and keeps them busy during nearly the whole season for field work. By referring to the data given on page 20 it is seen that the average labor income on the cotton farm where the farmer owns his land is about $260 a year, while on the wheat farm it is about $1,560. These two types of farming also illustrate the relation between the amount of capital employed and the profit. The cotton farmer employs very little capital, and his capital income is less than $100. This, of course, will vary with conditions.

On the other hand, the capital income of the wheat farmer is over $1,000 per year.

One of the important problems under investigation in this section of the office is the number of horses which it is practicable for one man to use in all kinds of farm operations in all sections of the country. District leaders are instructed to give particular attention to this problem, but county agents and supervisors should also make observations on this point whenever the opportunity offers. In the wheat-growing sections of the State of Washington one man utilizes the power of from four to six horses in nearly all kinds of field operations. Is a similar practice feasible in other sections? A recent farm-management survey in the State of Illinois developed the fact that teams of four and five horses are common in that section, and the labor income of the farmers there is more than twice as great as it is in other regions where smaller teams are used.

In this connection particular attention should be given to the possibility of uniformity in the size of equipment from the standpoint of the number of horses employed. Thus, if a farm is large enough to justify employing four horses, would it be advisable to have practically all of the work on the farm done by four-horse teams and thus save the time of one man?

The place of mechanical power on the farm is being investigated in connection with the farm-equipment studies already outlined. (See p. 51.) Bulletin 170 of the Bureau of Plant Industry, entitled "Traction Plowing," deals with this subject.

The relation of profitableness in farming to the amount of capital employed, to the distribution of this capital between land, buildings, and other factors of production, and to the number of laborers employed are subjects that are studied largely in connection with farm-management surveys and farm-equipment investigations, which are conducted in another section of the office. (See under "Farm economics," pp. 40–53.) The results of such studies are utilized to the fullest extent in connection with demonstration work, which relates as much to the redirection and reorganization of agriculture as it does to the conduct of farm work.

In regions where farming is not generally profitable because the holdings are too small for the types of farming adapted to local conditions, farmers should be encouraged to increase the size of their holdings either by purchase or by leasing. It is also a part of the duty of those engaged in demonstration work to give information to farmers concerning the amount it is wise to invest in dwellings and other farm buildings, the number of work horses that could be profitably used, and the character and quantity of machinery and other equipment justifiable under any given conditions. In this connection the information given in bulletins issued by the Section of

Farm Economics of this office is of value. (See Bulletin 212, Bureau of Plant Industry, entitled "A Study of Farm Equipment in Ohio," and Circular 44, entitled "Minor Articles of Farm Equipment.")

The seasonal distribution of labor on the farm and the maximum utilization of minimum equipment which good seasonal distribution of labor renders possible is a subject to which representatives of this section of the office should give attention. (See pp. 14–21; also see the article entitled "Seasonal Distribution of Labor on the Farm," Yearbook U. S. Dept. of Agriculture for 1911.)

In most parts of the country on farms devoted to the ordinary field crops the working season may be roughly divided into the following periods:

(1) SPRING: Preparing land and seeding spring crops.
(2) LATE SPRING AND EARLY SUMMER: Cultivation of intertilled crops.
(3) MIDSUMMER: Hay and grain harvest.
(4) LATE SUMMER AND EARLY FALL: Preparing land and seeding winter crops.
(5) FALL: Harvesting fall-maturing crops (corn, potatoes, cotton).
(6) WINTER: Care of stock, repairing equipment, laying in fuel supplies, cutting timber, mending fences, etc.

Plowing for spring crops may occur during any of the periods 1, 4, 5, or 6.

To have the labor evenly distributed between these various periods increases the proportion of the time during which the farmer is profitably employed and reduces the amount of power and equipment required to farm a given area. It is only in exceptional cases that such even distribution of labor is not important (p. 17). On most farms it is highly desirable, and occasionally a farm will be found on which the seasonal distribution of labor is the critical problem. As stated previously in these pages, most systems of farming which have become general in a region are at least rough approximations to systems that are ideal in this respect. The problem then is usually not that of completely revolutionizing the system which prevails on a farm but rather that of making slight adjustments of the system to render it more satisfactory from the standpoint of labor distribution. Frequently a slight increase in the area of fall-sown crops will relieve the congestion of work in the spring and reduce considerably the number of work animals required on the farm. Sometimes a change in the order of the crops in a rotation will obviate the necessity of plowing some fields, for some crops leave the land in condition for certain others without plowing. Occasionally a farm will be found whose owner has attempted to break away from the current practice in the matter of crop rotation and has established a system that gives exceedingly poor distribution of labor. Such farmers usually see the error of their way after a few years, but they frequently lose not a little money before they realize what is wrong with the systems they have adopted. Farms of this character may need radical changes in the cropping system in vogue in order to secure a satisfactory distribution of labor throughout the season.

It is desirable that representatives of this section of the office should work out in detail a few systems of cropping, based on the crops commonly grown or that should be commonly grown in their territory, each theoretically perfect from the standpoint of the seasonal distribution of labor. The knowledge gained in working out these systems will well repay the effort required. Such work gives an insight into some of the important problems that arise in the management of the farm. It impresses on the mind what crops compete with each other for labor at the same season of the year and those that do not compete. The working out of a few such systems will enable the student of farm organization to see quickly defects of farm organization when these defects relate to seasonable distribution of labor, which they frequently do. It will also fix firmly in mind the different problems of organization on farms of different size. If the farm happens to be of just the proper size to give adequate employment to one man and two horses when the land is devoted to the ordinary field crops, the problem of its organization is very simple indeed. Attention has already been called to the fact that farms of this size are not only more common in the States of the Middle West than those of other sizes, but that farms of this size are increasing in numbers, while those that are somewhat less in area are decreasing in numbers in those States. On the other hand, in the older States, especially near the great market centers, these smaller farms are increasing in numbers, because there the problem of their proper organization has been worked out. One can hardly appreciate the full meaning of these facts without attempting to work out systems of farming for farms of different sizes with a view to obtaining on farms of various sizes adequate employment for the farmer and the capital, labor, and equipment that might be used to advantage on a given farm.

The attempt to work out cropping systems that give good distribution of labor also reveals the fact that the system of management adopted with a given crop is frequently governed to a large extent by the exigencies of farm operation. Thus, whether the land for a given corn crop shall be plowed in the fall or the spring is determined in practice more generally by the amount of work the system in vogue calls for at each of these two seasons than it is by any theoretical advantage in the matter of yield that would come from plowing at either of these two seasons.

In regions where systems of farming prevail that bring only a meager income to the farmer or are otherwise seriously faulty, as is the case with the single-crop cotton system of the South, it is necessary to work out systems which differ materially from those commonly found. In the cotton States, for instance, if single-crop cotton growing is best under the circumstances, the problem then is not one of farm organization but is that of securing the highest possible yield, and the principal problem to be solved is that of supplying abundant humus to the soil. But if land is abundant and labor scarce, and especially on farms where the owner and his family do the major portion of the field work, in order to increase the family income materially it is desirable to work out a system of farming that will permit the use of at least 2-horse teams in plowing cotton lands and in cultivating the crop, and then provide other crops which will fully occupy the time of the available labor and horse power when not required by the cotton crop.

The usual rotation recommended for the cotton region is cotton followed by corn, and that followed by winter oats, after which cowpeas are sown as a summer hay crop. But this rotation does not give an entirely satisfactory distribution of labor. If we add to it a fourth year of winter oats and summer cowpeas, or if we substitute for the cowpeas Japan clover (lespedeza) and leave it down two years, we increase the area one man can farm and secure a better distribution of labor during the year.

In order to be able to understand the effect a given enterprise has upon labor distribution it is necessary to be familiar with the details of the management of that enterprise. It is therefore an important part of the work of representatives of this section of the office to familiarize themselves with these details. The following information concerning every kind of farm enterprise should be secured:

(1) The kind and number of operations required by the enterprise.
(2) The dates these operations may or should occur.
(3) The crews (men, horses, and machinery) used in these operations.
(4) The amount of work each of these crews performs in a day.
(5) The percentage of time available for each operation at the season in which it is performed.

These details of enterprise management are highly variable. For instance, the kind and number of operations in growing the cotton crop are different on different farms in the same community and are widely different in different sections of the country. The same is true of practically every other farm enterprise. It is therefore necessary to study these questions broadly and to become familiar with the permissible variations in methods. Some of the problems involved in this study are complex and difficult. This is especially true of the crews used, the amount of work done in a day, and of the percentage of time available at different times of the year, especially for field work.

Every representative of this section of the office should study extensively the subject of standards of farm labor. They should read carefully what is said on this subject on pages 14 and 15.

An easy method of determining the percentage of time available for field work during any period of the year is as follows: Suppose it is known that during the months of August and September in a given locality one man with two horses can, on an average, plow, harrow three times, and drill 40 acres of wheat. The percentage of available time may then be found thus:

Time required for 1 acre in various farm operations.

Operation.	Day's work.	Time for 1 acre.
	Acres.	*Part of day.*
Plowing	1.75	0.571
Harrowing (3 times)	10	.300
Drilling	8	.125
Total		.996

It would require 40×0.996=39.8 actual days of work to put in this crop. Since there are 61 days in August and September, the available time is 39.8÷61=0.653, or 65.3 per cent—practically 2 days in 3 on an average. The available time at any other season may be found in a similar manner if the area that one man can manage during that season is known. The amount of work he can do in a day must also be known.

In examining the system of management on a farm with a view to determining its weak points it is helpful to tabulate, at least roughly, the labor required by the various enterprises during each of the principal work periods. Where the organization of the farm from the standpoint of the distribution of the labor is faulty this gives an important insight into the nature of some of the problems that confront the farmer. Then, if the field man is familiar with the details of management, especially the labor distribution, of a large number of farm enterprises, it is easy to suggest changes in the system of management which will reduce the amount of work at one period and increase it at another, and this will not only decrease the amount of horse power and machinery equipment needed during the busiest seasons but will give a fuller utilization of horse power and equipment throughout the year. Where a definite system of cropping is in vogue on a farm a well-worked-out labor schedule covering the whole year will be of great assistance to the farmer, and in many cases it is worth while to work out such schedules for individual farmers. They are useful in the management of labor and are always of value as a means of foreseeing what equipment should be made ready for work in the near future.

Most of the work of agricultural scientists has related hitherto to methods of conducting farm enterprises, and has had little to do with problems relating to farm organization or to the problems that arise in the conduct of the business of the farm. While methods of growing crops and managing live stock are only one of the factors of profitableness in farming they are an important factor. Hence, it is of the greatest importance for those engaged in farm-management field studies and demonstration work to study carefully the methods used by successful farmers everywhere. They should also familiarize themselves with the results of scientific investigations relating to the best methods of conducting all kinds of crop and live-stock enterprises. The methods used by farmers who make a satisfactory profit in farming may usually be safely copied by others unless better methods are known.

An excellent type of work, especially for the supervisors, who have charge of groups of counties, and for district leaders, who have charge of the work in a few States, is to select regions covering a few counties in which the agriculture is fairly uniform, or, if sufficiently uniform, the region may cover a larger area, and to make a detailed study of the agriculture of the region along the lines indicated in the following publications of the United States Department of Agriculture: Farmers' Bulletin 294, entitled "Farm Practice in the Columbia Basin Uplands"; Farmers' Bulletin 472, "Systems of Farming in Central New Jersey"; and Bulletin 215 of the Bureau of Plant Industry, "Agriculture in the Central Part of the Semiarid Portion of the Great Plains."

In such studies particular attention should be given to the prevailing types of farming and the reasons why they prevail, including a discussion of the general adaptability of these types of farming to local conditions. The study should include the cropping systems used, the methods employed in managing the various crops and types of live stock, the methods of soil management and the resulting yields obtained, the sizes of farms, and the general financial condition of the farmer. This work is similar to the farm-management survey work already described, but it gives more attention to the methods used on the farms and covers a much wider territory. Such a study should also include, as far as possible, the history of the changes in the local agriculture, with the causes underlying these changes. Such studies give the field man an excellent knowledge of the agriculture of the region, and when published are exceedingly valuable not only to farmers in general, but also to those seeking locations in which to purchase farms.

Representatives of this section of the office should note, whenever opportunity permits, all cases of by-industries which are not usually found on farms, such as broom making, sirup making, etc., that are used to fill in the gaps in the labor schedule. In connection with such industries an account should be obtained of the equipment and its cost, the season of the year when it demands labor or occupies labor otherwise engaged on the farm, the profit obtained from it, etc.

All representatives of this section of the office are instructed to make a record of all crop rotations found in practice, together with the farmer's reasons for following each rotation, or rather the reason for each of the crops in the rotation and the particular order in which the crops come. Study of this kind over a large area will soon show what is practicable and what is impracticable in the way of crop rotation in that region, especially if it is one in which crop rotation is quite generally practiced.

Similar records should be made of all cropping systems for specific purposes that are found. Thus, in some of the tobacco-growing regions, a rotation is used in order to increase the yield of tobacco. The character of such rotation should be recorded and reported to the office. On stock farms frequently the rotation is planned to meet the needs of the stock on the farm. Such rotations should be studied carefully. In studying any rotation attention should be given to the labor distribution it requires. It is also a part of the work of the representatives of this section of the office to plan cropping systems, either of a general nature or for specific purposes, for such farmers as may desire them.

Another subject for investigation by the representatives of this section of the office is the cost and practicability of different methods of performing the same work. For example, corn may be cut and shocked by hand; by means of a 2-row, 1-horse platform cutter run by two men, with or without an extra man to make the "horses" for the shocks and pick up scattered stalks and ears; or by means of a corn binder with or without a shocker attachment. Wheat may be bound, shocked, and thrashed; bound, shocked, stacked, and thrashed; headed, stacked, and thrashed; or it may be harvested by a combined header and thrasher. Manure may be distributed by hand from a wagon, or it may be distributed by means of a manure spreader. There are many other farm operations that may be similarly performed in a number of ways. The problem is to find the cost of performing the operation in each of these ways and to determine which is most profitable and most practicable under given conditions.

Another problem closely related to the foregoing is that of crew work, which is also studied in the Section of Farm Economics. It is important to study all kinds of farm operations that require a number of men, teams, and implements. For instance, in putting silage in the silo a study should be made of the number of men, teams, and implements, the work each does, and the relative time of beginning the work on the part of each member of the crew. Harvesting and stacking hay and harvesting, stacking, and thrashing wheat are all examples of crew work which should receive attention. District leaders and supervisors of groups of counties will have opportunity to make studies of this kind.

The relation of methods of marketing to profit in farming is a subject of special study in the Section of Farm Economics, but those engaged in farm-management field studies and in demonstration work are instructed to give the subject such attention as conditions permit. This matter is further discussed in connection with the details of the extension work.

There is probably no more profitable work in which representatives of this office are engaged than the improvement of old, well-established systems of farming. It is seldom that any system of farming is so well perfected on even a single farm that a few simple changes will not greatly increase the net profits. It may be a slight change in the rotation, the elimination of boarder cows, the use of lime to correct soil acidity, or some other slight change that can easily be suggested by one who has visited hundreds of successful farms which will change failure to success, not only on one farm but sometimes over large areas.

In the dairy districts of the Central West a large part of the gross income on many farms goes toward the purchase of brewers' grains, bran, and other concentrates. The successful production of alfalfa cuts out this great expense. Alfalfa, however, is often a failure without lime and inoculation, and is much improved by the addition of organic matter to the soil and by comparatively deep plowing. These farmers realize the need and the value of alfalfa, but few of them know how to grow it successfully. As soon as they learn how to get large yields of alfalfa their entire system of farming will become highly profitable at once. As simple a thing as soil inoculation has often greatly increased the yields of alfalfa and made dairying highly successful over large areas.

On sandy lands in the North the introduction of hairy vetch as a green-manure crop and as a seed crop has greatly increased the fertility of the soil and has added much to the net income from farms in these districts. The growing of mammoth, or zigzag, clover for seed on such soil was found to be profitable on a few of these farms and through the influence of our field men it is now grown profitably over large areas of the sandy districts.

Skillful and well-informed farmers who have not yet attained the financial success that will warrant heavy investment in pure-bred live stock and yet who are desirous of producing such stock have been placed in a position to get the required capital without the necessity of borrowing. This has been brought about by some of the field men by a very simple combination of the skill of the farmer and the money of the capitalist, and in every case in which this has been done the results have been satisfactory to both parties to the contract. The money is usually furnished by some one who is much interested in live stock, but who is so tied up with other business that he can not give enough attention to farming to look after the details of the work. As an illustration of how this works out in actual practice, an instance may be cited in the State of Wisconsin in which a few purebred Holstein cattle were purchased by one man and placed on the farm of another. The contract, which is to run for five years, requires that the farmer furnish all the feed, in return for which he is allowed all the milk. The farmer also receives one-half the proceeds from the sale of male calves, and no heifer calves are to be sold except by mutual consent until the maturity of the contract. At the time of settlement the original investment is returned to the investor. Of the increase the farmer receives one-third and the man who purchased the cattle receives two-thirds. This particular investment has proved highly profitable to all concerned.

This is a much more legitimate use of capital than the buying up of large tracts of arable land and holding them for a rise in value; in fact, the purchase of land for this purpose is not for the best interests of the country, while the investment of capital in all kinds of productive agriculture is to be commended.

A fertile 500-acre farm in central Michigan had been so badly managed that for 10 years it had not paid any interest on the investment and had scarcely furnished enough income to cover the running expenses. At the request of the owners, representatives of the Office of Farm Management visited this farm and studied the details of its management. On their recommendation, 4-horse machinery was substituted for 2-horse machinery, the poorest of the cows were sold and the money invested in good cows, a silo was built, and many other minor changes were made. It was also recommended that in addition to his salary the foreman be allowed 10 per cent of the net income after the expenses, not including interest, were paid. The owners objected to this at first, until they understood that for every dollar the foreman received in this way the owners would receive $9. They were then anxious to make this agreement. The first year after these changes went into effect the farm paid all expenses and 5 per cent interest on the investment of $60,000.

Not infrequently dairy farmers are found who are making no profit because their cows are not capable of producing enough. By inducing them to keep records of the product of each cow and then to dispose of those that fall below the standard unprofitable farms may frequently be made profitable.

In many sections of the country the systems of farming do not provide a sufficient supply of humus in the soil. For instance, in many localities in the Ozark region the leading crops are corn and wheat, and very little else is grown on many farms. It has been found that a rotation of corn, corn, cowpeas, wheat, wheat is well adapted to that region, and by sowing cowpeas in the first-year corn, wheat in the second-year corn for winter pasture, and cowpeas as a catch crop after the second-year wheat an excellent cropping system is obtained that not only keeps the soil well supplied with humus and distributes the work so as to employ the same number of teams at all times during the season for field work, but furnishes roughage that renders the system well adapted to almost any kind of live-stock farming. While this system is a marked improvement over those prevailing quite generally in this region, it introduces only one crop that is new to the farmers, and thus does not appear to them as a radical change from their present methods. It also builds up the soil rapidly. Many other illustrations might be given showing that apparently simple changes in the systems of farming found on many farms and frequently over entire regions will often suffice to convert poor systems into good ones.

The work thus far outlined for this section of the office relates to what may be called farm-management problems proper. There are many agronomic problems which are best studied in their relation to farm practice. This is especially true of those problems that are so broad that ordinary experimental methods will not solve them. Perhaps the most important general problem of this character is the relation of farm practice to crop yield, already mentioned in discussing special farm-management problems.

This is a problem in applied agronomy. Every farm that has a system of soil management which has been in vogue long enough to show its effect on crop yields has a lesson to teach regarding the relation of various practices to soil fertility. There are many farms of this kind. The aim of this work is to secure from each of these farms a record of every detail that affects crop yields, such as the varieties of crops grown, the character of seed used, the depth of plowing, methods of preparing seed bed, methods of intertillage, including the kinds of implements used, methods of managing and applying manure, the kind and quantity of manure used, and complete statements of the methods relating to the use of fertilizers, lime, etc. A record should also be made of the character of the soil and of the crop yields obtained. Large numbers of such records of farms distributed over wide areas will, it is believed, permit of such statistical treatment as will reveal the influence on crop yield of each of the factors mentioned. Comparatively little progress has been made on this problem by the experimental method, when it is remembered that it has probably received more attention than any other agronomic problem. The main reasons for this are our lack of knowledge of conditions existing within the soil, the great variability of the experimental results, and the limited application of results obtained in a given locality. The two latter difficulties can be overcome only by securing large masses of data from all the numerous soil types, such as it is possible to secure by a far-reaching study of farm practice. This is another type of work in which, on account of the great variability of experimental results, no great additional accuracy can be obtained by a highly accurate determination of yields. In such cases quantity of data is vastly more important than accuracy of single observations.

Before the full value of the method of farm-practice investigation was realized the problem of the relation of different types of farming to crop yields had been attacked by the experimental method in cooperation with the Kentucky and the Maryland agricultural experiment stations. At each of these stations extensive series of plat experiments were instituted, in devising which an attempt was made to provide a test of certain types of farming which would represent in a general way all types. In order to secure definite results it will be necessary to continue these experiments during a long series of years. In time they will form a useful check on the results obtained in the study of farm practice, even if the results are applicable only to the soil types on which the experiments are conducted.

Some features of the relation of farm practice to crop yield may very well be studied independently. One of these is the management of manure. Much study has been given to the chemical composition of manures and to the effect of different methods of handling manure on the loss of chemical ingredients. Yet farm methods are little better now than they were two or three generations ago. This is partly because the problem of manure management is a difficult one in practice, and farmers have been left to their own resources in solving it. The task has been too great for the average farmer. The object of the present study is to help the farmer in the solution of the problem of securing the benefits of the manures with the least expenditure of time, effort, and money. It involves a study of the equipment for saving manure and protecting it from the weather; the cost, adaptability, and care of this equipment; the point in the rotation at which manure is applied and the quantities used; the equipment for distributing manure, the cost and practicability of this equipment, the power required to operate it, and the labor cost of distributing manure by means of it; the quantity of available manure produced per head of stock of different kinds under different systems of stock management; the relative value of manure from different kinds of animals and of the same kind under different systems of feeding; the kinds of crops to which manure from different animals is best adapted; the methods of composting; the conditions which justify the expense of composting; the cost of manure when it is obtained from outside sources; the value of manure as measured in increased yields under different conditions, etc.

A related problem which may be studied independently and on which a bulletin has already been issued by this office is farm practice in the use of commercial fertilizers. (See Farmers' Bulletin 398, entitled "Farm Practice in the Use of Commercial Fertilizers in the South Atlantic States.") It involves a study on individual farms of the kinds of fertilizers used, with reference both to the fertilizing substances and to the percentage of fertilizer elements contained; sources from which the fertilizer is obtained; methods of mixing; proportion of various ingredients required to give mixtures of any desired composition; use of ready-mixed compared with home-mixed fertilizers; equipment required for storing, mixing, and distributing; cost and practicability of such equipment; cost, including labor and time required for mixing and for distributing; rate of application; crops to which applied; time of application; manner of application, whether broadcast on surface, in rows with the seed, in rows and mixed, or covered with soil before planting the seed; means used in keeping up the humus supply so as to make fertilizers more effective; relation to yields; cost of fertilizer; accumulative effects on soil and how to overcome injurious effects, etc.

Local agents in regions where commercial fertilizers are largely used, especially where they are used in large quantities, should ascertain what saving can be made by the farmers in buying fertilizer ingredients separately and mixing them themselves. If the saving is found to justify encouraging this practice it is well to give demonstrations in the home mixing of fertilizers.

Farm practice in the use of agricultural lime may also be studied as an independent problem. District leaders, State leaders, supervisors, and local agents should cooperate in ascertaining the sources from which agricultural lime may be obtained and the prices at which the lime can be delivered at local stations. Both local agents and supervisors should give careful study to the needs of the various soil types in their territory concerning lime and to the best practice in the use of this soil amendment. Important service can be rendered to farmers by helping them to secure a good quality of lime at the least possible expense.

Another special problem, which is a part of the general problem of the relation of farm practice to crop yields, is the use of green manures as a means of putting humus into the soil. A study should be made of the crops adapted to this purpose and the places they may best occupy in the cropping system, as well as the effect produced by the use of such crops.

WORK OF THE LOCAL AGENTS.

It is impossible to outline in detail the problems the extension worker will meet with in any given locality in advance of the actual investigation in the locality, because these problems are so numerous and vary so greatly with local conditions. The extension worker himself must investigate local conditions and determine the particular needs of the community in which he works. The suggestions which follow, therefore, are not presented with the idea that they cover the ground fully in any given case, or with the expectation that local agents will undertake any large number of the problems to which attention is called. The best results will usually be obtained by concentrating very largely on one or two, or at least a few, lines of extension work, giving only incidental attention to others. From year to year the lines on which effort is concentrated will change according to the exigencies of the case.

Before undertaking extension work in any locality it is an excellent plan for the extension worker to tabulate all available census data concerning the agriculture of the region. He should also construct a rainfall map from the available data of the United States Weather Bureau and in all western sections should familiarize himself with the seasonal distribution of the rainfall, as this is important nearly everywhere in the West. He should determine the length of the growing season and should become familiar with the geology of the region, and if the Geological Survey has made a topographic map he should secure a copy. If the Bureau of Soils has made soil surveys, copies of the soil maps should be obtained and studied with care. Study of this kind makes a man familiar with the region in a general way even before he visits it and puts him in a position to assimilate data gathered by the study of farm practice much more readily than if he did not have this general knowledge of the locality.

The extension worker should also familiarize himself with the organization of the cooperating State institution and of the United States Department of Agriculture in order that he may know the sources of information in these institutions and become familiar with the work of experts who can render service to farmers in his territory. He should especially become familiar with the literature of these institutions relating to the region in which he works.

In beginning extension work in any locality one of the first things to do is to hunt up all the successful farmers who can be found and to make a careful study of their work. This should include a study of the types of farming followed, the cropping systems used, methods of keeping up soil fertility, and the details of the management of each enterprise on the farm. For suggestions as to the manner of making such study, see what is said under the heading "Study of successful farms," on page 37 of this bulletin.

A striking advantage which arises from this study of successful farms is the fact that the field man soon acquires a vast amount of local knowledge which makes him a welcome visitor on any farm, for farmers are always eager to learn the methods of those whom they regard as successful. They will listen eagerly to a description of an actual farm or any of its methods, while they will look askance at any suggestion that has not been tried out in practice. Farmers' Bulletins describing in detail the system of management on a single farm are read eagerly, and bulletins of this kind have had a larger circulation than any other type of bulletin prepared in the Office of Farm Management. Farmers practically never undertake to follow in detail the systems outlined in these bulletins, but they do adopt certain practices from them that are adapted to their conditions. (See Farmers' Bulletins as follows: 242, An Example of Model Farming; 272, A Successful Hog and Seed-Corn Farm; 280, A Profitable Tenant Dairy Farm; 310, A Successful Alabama Diversification Farm; 312, A Successful Southern Hay Farm; 326, Building up a Run-Down Cotton Plantation; 355, A Successful Poultry and Dairy Farm; 364, A Profitable Cotton Farm; 432, How a City Family Managed a Farm; 437, A System of Tenant Farming and Its Results; 454, A Successful New York Farm. See also Bulletin 102, Part II, Bureau of Plant Industry, entitled "A Successful Dairy Farm.")

In studying the details of the management of individual farms it is well to give attention to the relation of the farmer to his hired labor. This involves a study of housing and boarding; laborers' privileges, such as the use of a horse and buggy on Sundays and holidays, the use of a garden, the keeping of cows, pigs, and chickens, and access to farm papers and other available literature; the personal relations of the farmer and his hired labor; permanency of employment; and the relation of all these factors to the difficulty of securing farm laborers and the efficiency of this labor.

In studying the agriculture of a community attention should be given not only to defects in methods, but to defects of organization. The extension worker should read carefully the discussion of farm organization and equipment in the first part of this bulletin. (See pp. 9–30.)

Not only is it possible for the extension worker to help the farmer in the matter of the selection of enterprises that are to constitute the basis of his business and in the details of the conduct of each of these enterprises, but he can render occasional assistance by giving advice on such subjects as the cost of farm dwellings and plans and cost of other farm buildings. (See the discussion of the "Cost of farm dwellings," pp. 29–30 of this bulletin; also Farmers' Bulletin 438, entitled "Hog Houses.") He can be of special help by giving advice concerning equipment in farm machinery and in the care of this equipment. The extension worker should also familiarize himself with the number of work horses required on farms of a given size and type, as well as the number of laborers at different seasons of the year. This information can be obtained in connection with the study of the work on successful farms.

The maintenance of crop yield should always be a major consideration. The man engaged in extension work should master this subject locally as well as generally, and wherever yields are less than they should be an effort should be made to correct this defect.

It is important that farmers should use good seeds. So far as practicable farmers should be encouraged to grow their own seeds and should be taught how to select and care for seeds for the next year's planting. Where it is not practicable for farmers to do this, it is well to encourage a few men in each locality to produce a high quality of seeds to be sold locally. But this should not be overdone, as there might not always be a market for the seeds. Where it is not practicable to have seeds grown locally, service should be rendered to the farmer by helping to secure good seeds from other localities.

It must not be forgotten that of the 6,000,000 farmers in this country many of them possess great ingenuity and originality, and in practical affairs these men frequently work out the solution of problems that are of general interest. Extended study of farm practice in any region will reveal many interesting things of this character.

The Office of Farm Management has issued a number of important bulletins relating to methods of exterminating some of the worst weeds of the country. (See Farmers' Bulletins: 279, A Method of Eradicating Johnson Grass; 368, The Eradication of Bindweed or Wild Morning-Glory; 464, The Eradication of Quack-Grass; and Circular (Document 416), Bureau of Plant Industry, entitled "The Wild Onion.") Local agents should familiarize themselves with such of these bulletins as are of local interest. Where there is a serious weed pest the methods for the control of which are known, the farmer should be taught this method. Where noxious weeds are found for which no method of control is known, the State experiment station and the Office of Farm Management should be notified. It is, in fact, an important part of the work of the local extension man to put farmers in touch with the work of the various experts of the Department of Agriculture and the cooperating State institution.

Particular attention should be given to the methods of preparing land for seeding, including the season of the year at which plowing is done, the depth of plowing, the methods of fining the seed bed, etc. The methods and the implements used in tilling intertilled crops should be studied carefully. Usually the practice of the most successful farmers should be the guide in local practice unless it is known that there are better methods. The possibility of using plows, harrows, and tillage implements of large size should receive attention. On farms that are large enough to justify the practice, and in regions where conditions permit, it is economy to use the largest practicable sizes of all field implements.

In the matter of insect pests and fungous diseases local agents are not expected to become experts. Generally speaking, the best they can do is to call to the attention of experts in the State experiment station and in the Department of Agriculture problems of this character when they arise locally. In many cases either the State experiment station or the proper office in the Department of Agriculture will be able to furnish directions which the local agent can apply or even which the farmers can apply under the direction of the local agent. This ought to be possible in the treatment of grain for smut and in the spraying of orchards. Frequently, also, the method of controlling insect pests can be handled in a similar manner.

In regions where there are orchards improperly cared for, the local agent should familiarize himself with orchard practice and give demonstrations in pruning and spraying, and also in picking, sorting, and packing fruit for the market. Some of the local agents have been very successful in this work and have greatly increased the income of farmers from the sale of fruit from orchards which before had brought the farmer little or nothing.

In any locality where some special crop, such as potatoes, tomatoes, apples, etc., is important, the local agent and the supervisors should make themselves familiar with the management of these enterprises in order to be able to teach farmers the most improved methods. (See Farmers' Bulletins 323, entitled "Clover Farming on the Sandy Jack-Pine Lands of the North"; 365, "Farm Management in Northern Potato-Growing Sections"; 491, "The Profitable Management of the Small Apple Orchard on the General Farm. See also Bulletin 124, Bureau of Plant Industry, "The Prickly Pear as a Farm Crop"; Circular 28, Bureau of Plant Industry, "Clover-Seed Production in the Willamette Valley, Oregon"; and Farmers' Bulletins relating to particular crops: also similar State experiment station bulletins.)

The marketing of the products of these special crops is usually one of the most serious problems that confront the farmer, and all assistance possible should be given in this matter. Particular attention should be paid to the size and the style of package which the market demands. Farmers should be made to understand that attractiveness is worth even more than intrinsic quality in the sale of farm products, especially those that are exposed for sale in retail stores in the form in which they leave the farm.

Many farmers will be found who are making the attempt to keep some kind of record of their financial transactions and the work on their farms. Such farmers should be put in touch with the work of the Section of Farm Economics of this office, where much attention has been paid this subject; also with such cooperating State institutions as are doing work along this line.

In most localities it will be found desirable to hold meetings at country schoolhouses or elsewhere for the discussion of timely subjects. At the proper season these meetings may be devoted to the discussion of such subjects as lime, its source, cost, where and when to apply; fertilizers, kinds to buy, quantities to use, how and to what crops to apply, prices, how to mix, etc.; potato culture; renovation of orchards; the farmer's garden, etc.

In reaching the farmers, free use should be made of local papers. Copies of all articles prepared for publication in this manner should be sent to the Office of Farm Management. It is an excellent plan to secure a list of the names and addresses of all the farmers in the territory of the local agent, with brief data concerning their farming. The possession of these names permits the preparation and distribution of timely circulars, which should in all cases be previously approved by those in general charge of the extension work, including the section leader in this office.

Local agents can be of much assistance to farmers by helping them to organize associations for such purposes as the cooperative marketing of fruits and truck crops, the purchasing of fertilizers and seeds, etc. It is not wise for local agents to accept official positions in such organizations, since they should be managed by the farmers themselves. The idea is to teach the farmers to help themselves. In many sections of the country local agents have organized farm-management clubs and guided them in the consideration of real farm-management problems.

All those who are engaged in agricultural extension work should keep in close touch with the rural schools and should attempt to interest both teachers and pupils in the boys' and girls' agricultural club work. Much service can also be rendered in the introduction of agriculture into the rural schools by giving advice to teachers concerning the nature of the work that can be done, and especially by putting them in touch with sources of information in the State colleges and in the Department of Agriculture.

BOYS' AND GIRLS' AGRICULTURAL CLUB WORK.

The Office of Farm Management employs a specialist whose business it is to assist State and local authorities in the organization and conduct of boys' and girls' agricultural clubs. The boys' corn clubs and the girls' canning clubs have been very successful wherever work of this kind has been undertaken and have aroused a great deal of enthusiasm for improved methods of farming and farm-household administration. Full information regarding the details of this work and the service the office is prepared to render in connection with it will be sent to any applicant. This work in the cotton States is conducted by the Farmers' Cooperative Demonstration Work; in other States by the Office of Farm Management.

UTILIZATION OF CACTI AND DRY-LAND PLANTS.

When the Office of Farm Management was organized and the work with grasses and forage plants transferred elsewhere the work with the cacti and dry-land plants was retained because of the personal interest of representatives of this office in certain important problems relating to these, and it has since been maintained in the Office of Farm Management at the request of those in charge of the work in order that they might be free from administrative details and thus be able to devote their entire time to the investigation.

The first investigations of the cactus as an economic plant represented a study of farm and range practice in the use of these plants as forage for cattle. This study revealed so much of interest that the data obtained in it were published and formal investigations instituted with a view of determining just what value the cactus might possess both as forage in its wild state and as a farm crop. A large collection of varieties and species was made, especially in our Southwestern States and in Mexico, but also from other parts of the world. These have now been grown for several years with a view of ascertaining their possibilities as cultivated crops. Plantations are maintained at San Antonio, Tex., Chico, Cal., and Brownsville, Tex.

The numerous spineless forms that have been investigated have proved to be very sensitive to cold and can be safely grown only in localities where the temperature does not fall below 20° F., and seldom reaches this minimum. These spineless forms make good chicken feed, are excellent succulence for the dairy, and are relished by hogs. Some use is also being made of the plants as a succulent feed for Belgian and other hares. This group of plants can be made a paying crop where the conditions of temperature and moisture are suitable.

Much time has been spent in working out the cultural details of the cactus when grown as a farm crop, such as the distance between the rows and between plants in the row, methods of planting, the methods and amount of cultivation required, the age at which the forage may be harvested, and the methods of harvesting. One great advantage of the spiny cactus is that all that is necessary in feeding it is to burn off the spines from plants standing in the field. Stock may then be given free access to the field, where they will confine their attention entirely to plants that have been thus artificially prepared for them. This makes the harvesting of the crop, as well as the feeding of the stock, a very simple and inexpensive matter.

Several feeding experiments have been conducted to determine the forage value of the cacti. At the present time such an experiment is being conducted in cooperation with the Bureau of Animal Industry of this Department. These investigations include the conduct of digestion experiments. An effort is being made to determine the proper place of cacti in the rations of live stock of different kinds and to determine the effects of continuous feeding of cactus forage for long-continued periods. The following publications relating to cacti have been published: Bulletins of the Bureau of Plant Industry, No. 74, The Prickly Pear and Other Cacti as Food for Stock; 116, The Tuna as Food for Man; 124, The Prickly Pear as a Farm Crop; and 140, The Spineless Prickly Pears; Farmers' Bulletin 483, The Thornless Prickly Pears; and Bulletin 91 of the Bureau of Animal Industry, Feeding Prickly Pear to Stock in Texas.

The range investigations being carried on by this office are designed to secure accurate data upon the following subjects:

(1) Assurance as to the possible recovery of run-down ranges of different types under partial and complete rest, and the rates at which recovery occurs.

(2) The possibility of improving the native ranges artificially.

(3) The carrying capacity of the ranges, present, normal, and possible.

(4) An estimate of the area and geographic distribution of the open range, with a summation of published topographic and climatic data relating thereto.

(5) The chemical composition of and the botanical and economic data concerning the different species of range forage plants.

(6) Range management with different kinds of stock with and without fence.

Several years ago an area of over 50 square miles of badly overstocked and depleted open range land in southern Arizona was set aside as an experimental range and placed under the control of this office. The land was fenced and the greater part of it has been allowed to recover naturally. The remainder was divided into several pastures and has been carrying stock, mostly cattle, all the time. Data as to the exact number of head upon known areas have been obtained for something over three years. The areas in question have been under the management of different men, each using his own judgment as to the best method of treatment, modified only in so far as necessary to secure accurate data.

Data as to the production of both spring and summer feed at various places on the large unstocked field have been collected for a number of years. For the past three years the grass crop on several areas 25 to 40 acres in extent within this large field has been cut and the quantity of hay per acre determined.

Thus far this experimental range has demonstrated that a range in southern Arizona will recover approximately its normal carrying capacity in three to five years if allowed complete rest. This fact was seriously doubted by experienced stockmen of the region before this series of experiments was commenced. It has also shown that with proper control this range will slowly improve while carrying stock almost up to the limit of its carrying capacity. Data upon this point show a slight general increase in carrying capacity of the areas under stock.

The hay-cutting operations and the collecting and weighing of the spring feed are beginning to furnish accurate data on the actual amount of feed per acre produced annually on the protected range. These data and those obtained from the records of stock actually carried on adjoining measured areas will give something definite as to the normal carrying capacity of this region.

Numerous attempts have been made upon this large area and on another area of about 2,500 acres to increase artificially the quantity of forage produced by seeding, tillage, and conservation of the rainfall and run-off. Many different kinds of forage-plant seeds have been sown and cacti of several different species have been planted in an attempt to secure increased productivity on the areas referred to, but only a nominal increase in the forage crop has been secured. The sowings of some of the native grass seed have given positive results in a few cases, but mostly such attempts have been fruitless.

Extensive attempts to retain the surface run-off by systems of low dams have given some improvements in the forage crop, but the expense was out of all due proportion to the results achieved. Results from tillage experiments have been negative in character.

On all field trips of the parties in charge of these investigations data are being collected as to the area of open range land in the arid region and its geographic distribution, in order to be able to map it roughly. Published meteorologic and topographic data which affect the natural distribution of the native forage plants are being compiled from time to time as opportunity offers. Field notes of the distribution and density of forage plants, especially of grasses, are taken at all times.

For several years specimens of all kinds of forage plants have been collected on field trips for chemical analysis. The procedure has been to collect a sufficient quantity for the chemist and to make one or more botanical specimens of the same material, with occasional photographs showing the habit and habitat of the species. Copious field notes are taken on the economic importance of the species. The material for analysis is sent to the Bureau of Chemistry for a quantitative analysis, this work being carried on in collaboration with that bureau. A large number of such analyses have already been completed and the botanical notes relating thereto collected in a form ready for publication. More than 100 species of important grasses and grasslike plants are listed. It is expected that this investigation will result in a reference work for the chemical and botanical data available on all species of wild forage plants.

The remaining work on the utilization of dry-land plants relates largely to range management, and as this is mainly a study of range practice, this particular line of work is closely related to the general work of the Office of Farm Management. The work in range management relates to the various methods of management of stock, particularly cattle and sheep, upon the native ranges of the arid region, and considers the methods in common use on fenced and unfenced areas and the relation of the business to the forage conditions of the different sections. Data as to the cost of various operations, the construction and care of machinery and equipment, methods of handling stock, causes of loss of stock, and methods of disposing of the output are collected and summarized. The data are obtained from experienced stockmen in different parts of the country working under different range, climatic, and commercial conditions.

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Issued November 30, 1912.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 260.

B. T. GALLOWAY, *Chief of Bureau.*

THE AMERICAN BEET-SUGAR INDUSTRY IN 1910 AND 1911.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., June 18, 1912.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 260 of the series of this bureau a manuscript entitled "The American Beet-Sugar Industry in 1910 and 1911," prepared by Mr. W. A. Orton and other workers in this bureau.

This continues the series of reports on the progress of the beet-sugar industry issued by the department for several years past.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE AMERICAN BEET-SUGAR INDUSTRY IN 1910 AND 1911.

THE WORK OF THE BUREAU OF PLANT INDUSTRY ON SUGAR BEETS.

GENERAL STATEMENT.

The work of the United States Department of Agriculture on sugar beets is centered in the Bureau of Plant Industry in so far as it relates to problems of crop production, such as culture, improvement, extension of area, and control of diseases.

Other bureaus of the Department of Agriculture handle other phases of this industry. The Bureau of Chemistry, through its Sugar Laboratory, investigates the methods of analyzing beets and the other products of manufacture, and investigates also the manufacturing processes as they affect the composition of the finished product and by-products. It also investigates the chemical composition of beets grown in various localities, with special reference to the effect of environment on the same, and is making studies of the rarer carbohydrates as they occur in the various products of the industry; the Bureau of Entomology deals with all insect enemies of the sugar beet; the Bureau of Statistics compiles the statistics of the sugar industry in connection with its work on other crops; while the Bureau of Soils has included in its soil surveys several important sugar-beet areas.

The sugar-beet work of the Bureau of Plant Industry is conducted under the clause of the appropriation act reading, "For the investigation and improvement of sugar-producing plants, including their utilization and culture." This includes studies of sugar cane and other minor sugar plants.

For purposes of administration this work is united with that on cotton and truck-crop diseases, forming the "Office of Cotton and Truck Diseases and Sugar-Plant Investigations," which is one of 30 subdivisions of the Bureau of Plant Industry. Other offices cooperate to promote the sugar-beet work. The Office of Farm Management conducts studies of farm organization and farm practices in sugar-beet districts; the Office of Congressional Seed Distribution furnishes seed for trials in new localities and assists in the breeding and production of American beet seed and the cooperative trial of standard varieties; the Office of Western Irrigation Agriculture carries on at its field stations on the reclamation projects a number of cultural experiments with sugar beets; and the Office of Dry-Land Agriculture does similar work at its field station at Mitchell, Nebr. Assistance is also rendered by the Laboratory of Plant Pathology in dealing with bacterial diseases of beets and by the Office of Agricultural Technology on diseases due to nematodes. The Office of Drug-Plant, Poisonous-Plant, and Physiological Investigations is just completing a study of the relation of oxidases to the curly-top of beets. The large and highly specialized organization of the Bureau of Plant Industry and the cordial cooperation of other bureaus in the Department of Agriculture give it unusual advantage in attacking problems requiring the combined attention of specialists in several lines.

OUTLINE OF PROJECTS.

The work on sugar beets falls into four groups of projects: Culture, Diseases, Improvement, and Extension.

BEET CULTURE.

The cultural work is at present done mainly in the western irrigated districts by Dr. C. F. Clark, Dr. C. O. Townsend, Mr. Harry B. Shaw, and others. It includes studies on the depth of plowing, the distance of planting, cultivation methods, the water requirements of beets, and the most effective rotations. Uniform standardized experiments covering these points are under way at the principal stations. All this work is comparatively recent, as it requires field stations, which were not available during the earlier years.

Closely affiliated with this line of work are the farm-management studies and beet-farm surveys being made by Mr. L. A. Moorhouse. The office also has a representative, Mr. E. C. Rittue, detailed for demonstration work in the Arkansas Valley, with headquarters at Holly, Colo.

BEET DISEASES.

The investigations on sugar-beet diseases are older, dating back to July 1, 1901, when Dr. C. O. Townsend began his work. The principal troubles include:

(1) The leaf-spot (*Cercospora beticola*), which occurs in the Eastern States and as far west as Colorado. It has been shown that this disease can be controlled in Michigan by spraying with Bordeaux mixture and a bulletin is in preparation by Dr. Townsend giving the results of early experiments. The serious epidemics of recent years in the Arkansas Valley have led us to undertake an exhaustive study

of this disease and its relation to environmental factors, in the hope of discovering methods of control better suited to western field conditions. This work is now centered at Rocky Ford, Colo., in charge of Miss Venus W. Pool, who is assisted by Mr. M. B. McKay.

(2) Curly-top, a disease induced by the attack of the leaf hopper (*Eutettix tenella*), received much attention during the years 1902 to 1909. At present the control of this trouble is under investigation by the Bureau of Entomology, but the Bureau of Plant Industry is endeavoring to learn the real nature of the effect produced by the insect. Work on the curly-top is being done in the field by Mr. Shaw and in the laboratory by Mr. F. J. Pritchard and Dr. E. W. Olive, of the South Dakota Agricultural Experiment Station.

(3) Damping-off, or seedling troubles, and root-rot have been studied at intervals for some years. This line of work has been extended and will occupy the entire time of Mr. H. A. Edson.

(4) Crown-gall and another related bacterial disease have now been studied quite exhaustively by Dr. Erwin F. Smith, Dr. Townsend, and Miss Nellie A. Brown. Important as is this disease to other plants, it is not serious on sugar beets, and our work on this and other minor beet troubles is at present limited, in order to concentrate our efforts on important projects.

(5) The sugar-beet nematode (*Heterodera schachtii*) and the root-knot nematode (*H. radicicola*) were found some years ago by Dr. Ernst A. Bessey to threaten to establish themselves in our beet districts; hence, in order to adequately plan measures for their control, a general survey of the situation is being made the present summer by Mr. L. P. Byars.

IMPROVEMENT OF THE SUGAR BEET.

The improvement of the sugar beet by breeding includes several related projects under the general charge of Mr. Pritchard, with the cooperation of other members of the staff.

The most important project is that for the production of American varieties adapted to our various climatic conditions. This work has been under way for several years, with the principal center at Fairfield, Wash., in cooperation with Mr. E. H. Morrison and under the general direction of Mr. J. E. W. Tracy. The work in Washington has now been completed and the field headquarters removed to Madison, Wis., with branches at several other points. Mr. J. F. Reed, who has been employed on this work for some years, has resigned to engage in private work and is succeeded by Mr. C. M. Woodworth, formerly of the South Dakota Agricultural Experiment Station.

The results of the single-germ breeding, to which attention has been drawn in previous reports, are now being reviewed, to secure an accurate measure of the progress attained. The details of this work have been attended to, for the most part, by Mr. Rittue and Mr. J. M. R. Adams.

In all the beet breeding the results are being recorded in a way that will throw light on the fundamental principles of heredity involved.

To promote the establishment of an American beet-seed-growing industry, the bureau is testing the adaptability to this crop of a number of different localities, including the Shenandoah Valley of Virginia and points in Wisconsin, Michigan, Utah, and other States.

The laboratory equipment needed to make the analyses for the breeding work outlined is quite extensive. Provision will be made by Mr. W. B. Clark for making 60,000 determinations of sugar content at Madison and a somewhat less number, with other coordinate tests, at Garden City, Kans., in addition to those done for us by the Bureau of Chemistry at Washington.

EXTENSION OF THE BEET-SUGAR INDUSTRY.

Much work is done each year on the extension of the beet industry. Seeds are sent out to cooperating farmers, with directions for beet culture, and samples are obtained in the fall for analysis. By these means, supplemented by field surveys, information is secured concerning the adaptability of new sections to beet growing. There is a heavy correspondence on many questions of a varied and general nature.

VARIETY TESTS.

For several years the bureau has conducted comparative tests of the standard varieties of sugar beets. All those kinds or brands in use by two or more sugar companies in the United States are included. Only 11 varieties are included in the tests of the present season, and these varieties are planted at the following points: Holland, Blissfield, and St. Louis, Mich.; Decatur, Ind.; Waverly, Iowa; Madison, Wis.; Garden City, Kans.; Rocky Ford, Holly, and Longmont, Colo.; and Ogden, Utah. Mr. Tracy has had supervision over this work since its inception.

FIELD STATIONS.

The principal points where field work is being done are Garden City, Kans., Madison, Wis., Ogden, Utah, and Rocky Ford, Colo., as follows:

Garden City, Kans.—In cooperation with the United States Sugar and Land Co. Here a new brick laboratory building and 20 acres of land are furnished by the cooperators and the bureau maintains a staff of three or four workers. The character of the building is shown in figure 1. This laboratory is in charge of Dr. Townsend.

Madison, Wis.—In cooperation with the United States Sugar Co. Rented quarters in the factory building are utilized as a chemical and breeding laboratory. The field work is on rented land near by. The pathological studies of Mr. Edson on damping-off and root-rot are being conducted in the laboratory of the University of Wisconsin.

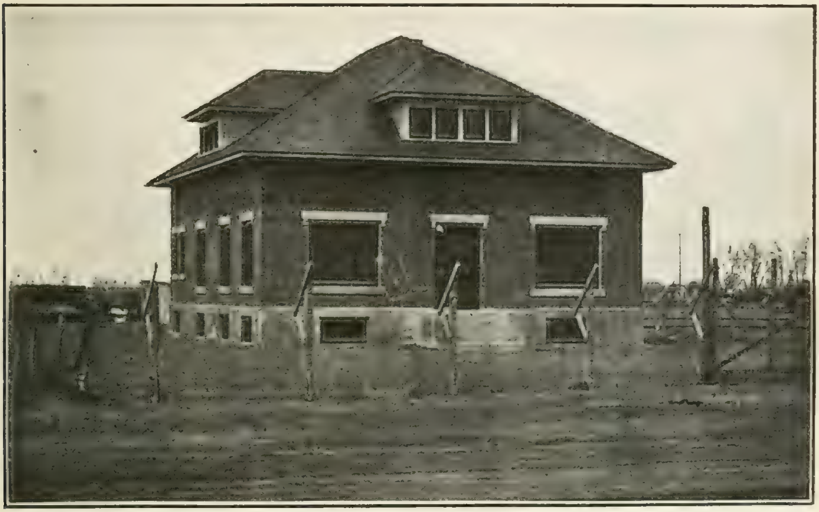

FIG. 1.—Sugar-beet laboratory at Garden City, Kans.

Ogden, Utah.—Work by Mr. Shaw and Mr. Adams on beet culture and breeding and on curly-top is under way on 5 acres of rented ground.

Rocky Ford, Colo.—In cooperation with the American Beet Sugar Co. For the leaf-spot investigations a special laboratory, in charge of Miss Pool, is maintained at this point in the building of the cooperating company. A greenhouse has been built for the work and additional field plats are utilized as needed.

GENERAL REVIEW OF THE BEET-SUGAR INDUSTRY IN THE UNITED STATES.

By W. Blair Clark,

Assistant Chemist, Office of Cotton and Truck Diseases and Sugar-Plant Investigations.

INTRODUCTION.

As a result of the development of beet growing in Europe it was early concluded that the most favorable belt for the production in this country would be found to lie along either side of the summer isothermal line of 70° F. The earlier publications of the Department of Agriculture on the subject of sugar-beet growing[1] contained maps showing the location of this theoretical sugar belt. This isothermal line is also shown on the two maps which accompany this article, but it is felt that the growing of sugar beets here has now developed to a stage at which we can profitably place the emphasis on those places where success has actually been attained on this continent.

At the present time commercial sugar-beet growing in the United States has been somewhat extensively developed in three main localities, which may be conveniently designated as the California, the Intermountain, and the Great Lakes regions. Beet growing is conducted in the southern and central parts of California. The Intermountain region includes Colorado, Utah, and Idaho, with recent outlying developments in extreme western Kansas and Nebraska, with possible development in Nevada in prospect. The Great Lakes region includes Michigan and Wisconsin, together with adjacent parts of Ohio, Indiana, and Illinois. Besides these three thoroughly established sections, there are a few scattered factories, some of which give indications of considerable future growth in the localities represented, while the experience of others seems to show that little can be expected from the sections where they are situated. The most promising of these isolated factories are in the upper Mississippi and the Missouri Valleys, in Minnesota, Iowa, southeastern Montana, and eastern Nebraska.

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[1] Bulletin 52, Division of Chemistry, U. S. Dept. of Agriculture, 1897.

CLIMATOLOGICAL CONDITIONS.

In the two accompanying maps (Pls. I and II, in pocket) the beet-growing sections of the several States are shown shaded in red, and the factory locations are given in the same color. A few factories were not operated the past season, and these locations are designated by circles instead of solid dots. Factories which have been permanently closed or dismantled within the last few years are shown in black. No effort has been made to show the locations of the earlier factories that failed.

In explanation of the shading which shows the beet-growing areas it should be said that these sections are indicated only in a general way. On a map of this scale it would be impracticable to do more than to indicate in a general way the counties and parts of counties where beets are produced in a greater or lesser quantity. In California, for example, except in the section around Los Angeles, the country is quite rough and the agricultural operations are of necessity confined to the valleys and the lower slopes. In the Intermountain region the same condition prevails, with the additional restriction that the ground must lie so that it can be irrigated. In the Great Lakes region, where considerable areas are covered by shading, it must be remembered that not every farm grows beets and that some parts of counties thus shown may produce few or none.

RAINFALL.

On Plate I the heavy red lines show the mean annual rainfall in inches for the different parts of the country. For example, all the localities where the average annual rainfall is 40 inches are joined by one of these lines; all localities where the average is 35 inches are joined by another line. All points located between these two lines have an annual precipitation averaging between 35 and 40 inches. By devoting a little study to these lines the reader can readily compare the rainfall in different parts of the country.

But in studying rainfall it is not sufficient to know merely the total annual precipitation for a given locality. There are two other points a knowledge of which is of equal importance with this. These are the distribution of the rainfall throughout the year and the expected variation from the mean. The beet crop for its proper growth and maturity requires a good supply of moisture during the planting and growing seasons, but it will not begin to store sugar in quantity until the beets have been subjected to a season of dry weather at the end of their growing period. Last year the Arkansas Valley crop was materially reduced because of the lack of irrigation water in abundance early in the season. In the Great Lakes region, on the other hand, prospects for a bumper crop were effaced by rains which continued throughout most of the harvesting period.

The average rainfall for each month and the frequency with which variations from this average may be expected to reach a given value at a number of selected stations in the beet-growing regions are shown graphically along the upper and lower margins of Plate I. The zigzag line that delimits the colored portion of each diagram indicates the mean precipitation for each month of the year as determined from observations extending over the number of years shown by the figures in heavier type at the bottom of each column. The scale of inches by which the zigzag line is located may be seen along the left margin of the diagram. Small light-face figures in the columns for the various months (those above the red being just above the scale lines, while those within the colored portion are just below these scale lines) show the number of seasons of the entire number on record in which the rainfall during the particular month noted was more or less than the number of inches indicated by the line to which the figure is adjacent. Perhaps this explanation can be better understood by citing a concrete example. Referring to the diagram relating to Findlay, Ohio, it will be observed that the highest average rainfall of the year occurs in June, the precipitation for that month being 4 inches, as shown on the scale. The number at the bottom of the column is 19, such being the number of years covered by the records from which this average was calculated. Now, in this same column the figure "5" just above the line indicating a 5-inch precipitation means that in 5 seasons out of the 19 on record the June rainfall was more than 5 inches; similarly the "1" above the 8-inch line means that in only one of these years did it reach or exceed 8 inches. Passing below the red margin, the "9" just below the 3-inch mark indicates that in 9 out of the 19 years June had less than 3 inches rainfall; while the "0" a little lower in the column shows that not once during the whole period did the precipitation fail to reach 1 inch for the month, although in both February and October the precipitation was less than 1 inch in 4 of the 19 years.

Thus, one can ascertain from these diagrams not only the mean precipitation for each month of the year, but also the number of seasons in a series in which the variations from this mean will be extreme, this latter constituting one of the essential factors in calculating the average crop results of a period of years. It remains but to add that the stations for which these diagrams have been prepared are fairly typical of the sections in which they are located. The first four, for example, all belong in the southern section of the Great Lakes region, previously defined, and it will be readily seen that they are quite similar, both as regards the mean monthly precipitation and the variations therefrom.

LENGTH OF THE GROWING SEASON.

The length of the growing season is another element in determining crop results. This subject is treated graphically on Plate II. The heavy red lines on the map connect points having growing seasons of equal average length, ranging from the shortest season in the North to those of greatest length in the South. As the length of the growing season is chiefly limited by the latest killing frosts in the spring and the earliest in the fall, tables are printed on the margin of this map showing such data for a number of selected stations in the beet-growing sections.

The frost data for 43 selected stations is given in tabular form on the lower margin of the map. In this table the first line of figures shows the number of years during which the record has been kept. Three dates in the spring have been arbitrarily selected, and in the column devoted to each station the number of seasons of those on record in which the last spring frost was subsequent to these dates has been entered. Thus, at Findlay, Ohio, in 13 of the 19 on record, killing frosts occurred after April 30, while in only two years such frosts came later than May 20. Similarly, only once did a killing frost come before September 20, while 10 are recorded previous to October 5. As only one of these frosts was before September 20, it is obvious that the remainder, i. e., 9, occurred between September 20 and October 5. In other words, practically half the growing seasons at this station are terminated between September 20 and October 5, and one-fourth of the seasons end between October 5 and 20.

Passing to the lower lines of the table, showing variations in the length of the growing season, it is observable that at no time during the 19 years of the record at Findlay was the season less than 130 days. For 8 years, or nearly half the number recorded, the period during which active growth might continue was between 150 and 170 days. A very cursory study of this chart will show that, excluding the subtropical Arizona and California sections, practically all our sugar beets are grown in places where the length of the season is seldom less than 130 or more than 170 days.

PROGRESS IN THE SECTIONS.

Following the above general survey we may now enter into a more detailed discussion of the several regions mentioned.

CALIFORNIA.

California was the first State in which commercial success was assured by the establishment of satisfactory relations between technically equipped growers and manufacturers, although it was not the first State in which efforts were made to produce beet sugar. The factory at Alvarado is the oldest in the United States now in operation. During the 1911–12 campaign 10 factories in the State were making sugar. As may be seen on Plate I, some of these factories are quite closely bunched; whether too closely for the good of the industry remains to be seen.

The exceptional soil and climatological conditions in California seem peculiarly adapted to the production of beets with a high sugar content. While their reported yield per acre is not so great as that of some other States, the sugar content is decidedly in excess of any other, so that with an acreage considerably less than that of Michigan the total yield of sugar is much more. The calculated yield per acre for the past season was very nearly 3,310 pounds. Many of the California soils are very retentive of moisture, so that with an annual rainfall far below that of the central and eastern part of the country beets can be grown successfully without irrigation. The little rain which they have is usually so nicely distributed through the early and middle seasons of growth as to leave almost ideal conditions for the period of ripening, with its accompanying storage of sugar in the cells. This ripening process is also materially assisted by the alternation of cool nights and warm days, a condition which seems best suited to the formation and storage of sugar in this plant.

Beets are reported as being grown in practically every one of the western counties from Alameda, which touches San Francisco Bay, south to San Diego, while Glenn, Butte, Solano, and Yolo Counties are listed in the reports of the Sacramento River valley.

Statistics for the entire production of this and other States are given in Table X (pp. 69–70), while the climatological data are shown on Plates I and II (in pocket).

THE INTERMOUNTAIN REGION.

The principal beet-growing territory of the intermountain region is included in Colorado, Utah, and Idaho, with outlying sections in western Kansas and Nebraska. There is also a small section in eastern Oregon, on which the 1911 crop was probably the last that will be raised, and a new factory has just been completed at Fallon, Nev. It is expected that the coming crop will open the production for the last-named field. This entire region is a part of the country where successful agricultural operations are dependent upon irrigation. It may be conveniently subdivided into the Salt Lake section, including central and northern Utah and the southeastern corner of Idaho; the Grand Valley in western Colorado, the Rio Grande and San Luis Valleys in south-central Colorado, the Arkansas Valley in southeastern Colorado and southwestern Kansas, the Platte Valley in northeastern Colorado and western Nebraska, and the Snake Valley in southern Idaho and eastern Oregon. The expectation is that the Carson Sink area will furnish most of the beets for the Fallon, Nev., house.

Salt Lake section.—The beginnings of successful sugar production in the Salt Lake section were at Lehi, Utah, in 1891. The next factory was built at Ogden in 1898, and the remaining mills have been erected since 1901, that at Elsinore, which began to make sugar during the 1911–12 campaign, being the most recent addition.

In many ways the conditions in this section seem almost ideal for farming. With a rich fertile soil and abundant irrigation water under complete control, the farmer is enabled to handle his crops to the very best advantage possible. However, it is not an unmixed good, for this section is occasionally subject to blighting winds and unseasonable frosts which play havoc with the crops. Sometimes, also, the mountain rainfall and snowfall, which supply the irrigation water, are deficient. On the whole, however, the conditions are among the best that are to be found anywhere, and while the sugar content of the beets is not quite so good as in California the yield of beets per acre is better. During the past season the estimated yield of sugar per acre was about 3,275 pounds, which is not far short of the California figure.

A noticeable feature of the Utah and Idaho production is the smallness of the individual growings. The plats probably do not average more than 5 acres each. In this way practically the entire work of planting, cultivating, and harvesting is kept within the grower's family, so that the labor problem is much less acute than in some other sections.

During the past season beets were grown in Boxelder, Cache, Weber, Davis, Salt Lake, Utah, Wasatch, Carbon, Sanpete, and Sevier Counties in Utah and in Oneida County, Idaho.

Grand Valley.—Only one factory is located in the Grand Valley, that at Grand Junction, Colo. It began operations in 1899. While this section is comparatively small in acreage and tonnage, it is reported to be gradually increasing. The length of territory covered, however, is quite extensive, some shipments being made from points a hundred miles distant. The growing is confined, of course, to the valleys. Delta, Mesa, Montrose, and Garfield Counties in Colorado and Emery County, Utah, are all represented.

Rio Grande and San Luis Valleys.—The factory at Monte Vista, Colo., made its first run during the season just closed. It opens up a new territory in the San Luis and upper Rio Grande Valleys. Beets for the first campaign were grown in Rio Grande, Saguache, and Costilla Counties.

Arkansas Valley.—The entire growth of the industry in the Arkansas Valley section has taken place since 1900, the year in which the two oldest factories, those at Rocky Ford and Sugar City, began slicing. Seven factories now operate in this territory, including the one at Garden City, Kans. For economic reasons one or two of them did not run during the past season. Owing to a short crop it was cheaper to transport beets to one factory and keep it busy rather than to operate two, both on part time.

The beets of this section are grown in El Paso, Pueblo, Otero, Crowley, Bent, and Prowers Counties, Colo., and in Hamilton, Kearny, Finney, and Gray Counties, Kans. In another article in this report Mr. Moorhouse gives an interesting discussion of the conditions in this valley; hence nothing further will be said here on the subject.

Platte Valley.—The Platte Valley territory in northeastern Colorado and western Nebraska contains 10 factories, all under the management of one company. The oldest of these factories began slicing in 1901. The beets of this section are grown in Larimer, Weld, Adams, Morgan, Washington, Logan, and Sedgwick Counties, Colo., and Scotts Bluff County, Nebr. The past season is reported as about normal in the total quantity of beets produced, while the quality was improved and the crop worth more to the growers. It would appear that concerted action on the part of the Colorado growers has enabled them to command a somewhat better price than formerly for their output.

Snake Valley.—In the Snake Valley territory the only encouraging signs at present are in eastern Idaho, factories being at Sugar City, Idaho Falls, and Blackfoot. The counties supplying beets for these three centers are Bonneville, Fremont, Bingham, and Cassia. Production began in 1903, since which time both the quantity of beets grown and the price paid to the farmers for them have increased. The establishment of a factory at Nampa, in western Idaho, seems to have been ill advised. No efforts were made to grow beets there for the past campaign. Operations at La Grande, Oreg., have also been discouraging. The short run made there the past season is reported to be the last, as the factory is to be moved to Burley, Idaho. The beets were raised in Union and Wallowa Counties.

Statistics pertaining to production in the Intermountain region are given in Table X.

THE GREAT LAKES REGION.

For convenience the Great Lakes region may be subdivided into an upper and a lower section. The former includes the northern parts of Michigan and Wisconsin, while the latter takes in the southern portions of these two States and northern Ohio, Indiana, and Illinois. The first commercial experiments which really foreshadowed the success of the beet-sugar industry were made in this region, but the success portended by those experiments was not actually forthcoming here until after it had been attained in the West. While the oldest of the present factories dates only from 1899, no less than 25 operated in this territory last season, and several others are projected for the near future.

Conditions in this region are, of course, quite different from those in the Snake Valley, particularly with regard to moisture. This region being in the humid section of the country, irrigation is not practiced. Normally, the length of the growing season is sufficient and the rainfall is ample and suitably distributed throughout spring and summer, with dry, increasingly cool, fall weather to afford conditions needed for maturing sugar. It is to be noted, however, that in the case of the last crop this normal condition of affairs was seriously altered. A fine growing season was followed by an unusually rainy ripening and harvesting period, so that what had given promise of being the greatest crop ever produced turned out very poor in quality, although of fair tonnage. Many tons of beets were so poor that the factories were unable to work them after having received and paid for them.

In Michigan and Wisconsin beets are raised in practically all except the extreme northern counties; they have been introduced into most if not all of the northwestern counties of Ohio; and the number of growers throughout the northern counties of Indiana and Illinois is increasing sufficiently to justify further investment in factories.

So far, the development has been very much less in the upper section than in the lower. Only three of the factories, those at Charlevoix and Menominee, Mich., and Chippewa Falls, Wis., are in this section; and it is reported that the factory at Charlevoix is soon to be moved to Ohio. The factory at Menominee, Mich., receives its beets chiefly from Wisconsin, some coming from as far south as the middle of the State. Expansion in the Lakes region seems to be tending southward rather than toward the north. The factory at Findlay, Ohio, made its first run for the 1911–12 crop; others are building at Rossford (near Toledo), Ohio, and Decatur, Ind., while plans are being promulgated for still others at Pigeon, Mich., and Columbus and Ironville (Toledo), Ohio.

Production and other statistical data are given in Table X, while information concerning the climatology is given on Plates I and II.

ISOLATED FACTORIES.

A few widely separated factories remain for detailed consideration. With but one exception these factories are all located in what may ultimately develop into the most extensive beet-growing territory in the United States, the Missouri-Mississippi Valley region. At present this portion of the country is devoted chiefly to extensive methods of agriculture, but with the continued growth in population, involving both a larger number of people per square mile and the need for a greater quantity of food, more intensive methods will become necessary. And in the drift toward such methods sugar beets will undoubtedly become of increasing importance.

Minnesota.—One of these scattered factories is at Chaska, Minn. The beets are being grown for it in Carver, Scott, Le Sueur, Rice, McLeod, and Martin Counties. The tonnage per acre and the sugar content have both been good, and it is expected that the 1912 crop will be more than double that of 1911.

Iowa.—Beets for the factory at Waverly, Iowa, come from Mitchell, Humboldt, Hardin, Wright, Cerro Gordo, and Butler Counties. This area covers a range wide enough to supply more than one factory when a sufficient number of farmers in these counties can be induced to make contracts. Neither the yield nor the quality reported for the past season was of the best, but this factory began slicing only in 1907, and reports show that in that time both the yield and the quality have been improving. The experience of all localities goes to show that it takes several seasons of trial before the farmers generally are able to produce really good beets in profitable quantity.

Nebraska.—The small factory at Grand Island, Nebr., has been in operation since 1890, but for some reason growth in that section has not been very rapid.

Montana.—The factory at Billings, Mont., is one of the largest and is said to be one of the most profitable in the country. Most of the beets are grown in Yellowstone County, a few in Carbon. For the past season a greater yield than ever before was reported and of greater value per ton to the grower. The beets of this section are the only ones that rival those of California in sugar content.

Arizona.—The factory at Glendale, Ariz., has operated under more or less disadvantageous conditions ever since its establishment in 1904. Uncertainty about irrigation water has made it difficult to obtain a sufficient acreage. Last year the yield per acre was fairly good, but the sugar content was not of the best; yet improvement in these respects is noted.

Canada.—Three factories are operated in Canada. Two factories are in the Province of Ontario, at Wallace and Berlin; the third is at Raymond, Alberta. The last mentioned has not been heard from at this writing, but the factories at Wallace and Berlin both report an increase in the yearly output. At Berlin in particular, the tonnage of beets in the 1911–12 campaign was nearly double that of the previous one and almost trebled that of 1909–10.

BY-PRODUCTS.

Considerable advance has been made in this country in the use of the by-products of the beet-sugar industry, but we are still far behind Europe in this important respect. For the present at least, the tops and pulp are the most important of these by-products. But the molasses, where recovery processes are not used, the exhausted lime, and the waste wash waters from the factories are of value.

TOPS.

A crop of 12 tons per acre of beet roots, containing about 22½ per cent of dry digestible substance, is accompanied by about 9.6 tons of fresh tops, containing approximately 15 per cent of dry digestible substance. This gives a total of 4.14 tons of dry digestible substance per acre, a growth that is equaled by few if any other farm crops.

At present practically the only manner in which the nutritive value of these tops is utilized is by feeding them on the field. Under such conditions their market value is reckoned at $2 to $4 per acre. This practice is decidedly wasteful, however, and their value would be much greater if siloed in trenches and fed to the stock gradually and in a way that would avoid the loss due to trampling underfoot by the cattle. There are few cases wherein the saving effected would not more than balance the cost of siloing the tops.

Taking $3 per acre as the average market value of the tops when fed in the field, the 1911 crop of 473,877 harvested acres would have an estimated value slightly in excess of $1,420,000, while that of the 1910 crop would have been a little less than $1,200,000.

PULP.

At the present time three methods are practiced for the utilization of the exhausted pulp. In two of these methods the pulp is used wet and in the third it is dried. In one of the wet methods the water with which the pulp is flushed out of the diffusion cells (with still more added if necessary) is used as a floating medium with which to pump it out into large pit silos, where after fermentation it is fed to fattening cattle. In some instances this feeding is done by the sugar company as a side issue to its own operations, while in other cases the pulp is sold to cattle feeders who have their pens near the factory.

By the other wet process the pulp flushed out of the diffusion cells is drained and squeezed slightly, from which there results a mass containing about 90 per cent water and of which the weight is about 40 per cent of that of the beets from which it was produced. In this condition the pulp can be transported for short distances either in bags or bulk, and when so treated it is usually sold to neighboring farmers, who haul it home and feed immediately or silo it.

The present selling price of such pulp ranges from 25 to 35 cents per ton. In making up the estimates here given it is taken at 30 cents per ton.

The 10 per cent of dry substance in the squeezed pulp is about one-tenth protein and nine-tenths carbohydrates. Most of it is fed after fermentation in the silo, which involves considerable nutritive loss. A much more economical method of handling is to dry the pulp before it has had an opportunity to ferment. A number of factories now follow this method. The dried material contains about 8 per cent digestible protein and from 70 to 80 per cent of digestible carbohydrates. Pound for pound, its dry substance is of greater food value than that of fermented pulp. In use it should be wet before feeding. This dried pulp is found to be particularly valuable as a dairy feed. Like corn silage, it may be used to lessen the amount of corn, bran, and other concentrates in the ration.

One ton of beets will produce approximately 90 pounds of dried pulp. Of the 5,062,333 tons of beets sliced during the 1911–12 campaign very nearly 1,850,000 tons were worked in factories which report pulp driers as a part of their equipment. From these figures it is estimated that about 83,000 tons of dried pulp were produced during the campaign. A conservative estimate would place the factory value of this pulp at $15 per ton, which would make the aggregate value of dried pulp $1,245,000. The remaining beets, somewhat in excess of 3,200,000 tons, would have made more than 1,285,000 tons of wet pulp, with an estimated value of $385,580, which, added to the value of the dried pulp, makes a total of $1,630,580 for all pulp.

MOLASSES.

Factories using the Steffens osmose recovery process have practically no molasses left. With the osmose process about 2 per cent remains, while where such processes are not in use the exhausted molasses, under favorable operating conditions, amounts to about 3 per cent of the weight of beets sliced. Sometimes, where the purity has been low or the beets have been injured by late rains or early freezes, the molasses may reach double this figure. Of the more than 5,000,000 tons of beets handled during the last campaign, nearly 2,830,000 tons were sliced by factories which do not report the operation of either of the recovery processes mentioned. Of this amount, 1,320,620 tons were worked in the southern part of the Great Lakes region, where conditions were abnormally bad for the season, and from the somewhat incomplete data at hand it has been estimated that their molasses output was 4.5 per cent of the weight of the beets. This would give approximately 59,428 tons of molasses, which at a factory valuation of $10 per ton would have a total value of $594,280. In the Western States, where the season was more favorable to the production of good beets, 1,508,798 tons were sliced, the quantity of molasses being about normal. For the figure mentioned, i. e., 3 per cent of the weight of beets, this would give 45,264 tons, with a factory value of $452,640. Adding these two amounts gives $1,046,920 as the total estimated value of the molasses production.

This molasses contains about 50 per cent by weight of sugar and a varying proportion of alkaline and alkaline-earth salts of organic acids. It finds a somewhat varied use, a portion being fermented for the manufacture of alcohol and vinegar. It is being increasingly used for feeding purposes, as at the present price of $10 to $10.50 per ton it constitutes one of the cheapest elements of a mixed feed. Experiments have shown that in the feeding of draft animals molasses can be substituted for grain, pound for pound, up to about 4 pounds per day per head. On most of the Cuban plantations all of the draft and riding animals, including horses, mules, and oxen, receive no feed whatever during the six months' harvest season except molasses and sugar-cane tops.

Feeding tests show that molasses possesses a tonic value in addition to the nutritive value of its contained carbohydrates. Besides being a good energy-producing feed for draft animals, it increases the milk production of cows and improves the appetite of fattening steers causing them to eat more heartily of other feed.

LIME AND WASTE WATER.

So far, the lime and waste-water by-products of the sugar factory have been but little utilized in this country. In only a few sections is their fertilizing value beginning to be appreciated. Where lime is needed, and many farmers who do need it fail as yet to recognize the fact, that from the sugar factory supplies the need in a cheap and efficient form.

The waste water from the factory also possesses considerable value for fertilizing purposes, although it can not be profitably conducted to any great distance from the factory. In using it care should be exercised lest it infest the ground with weeds. It is pretty sure to carry some seeds, as it contains the washings from the uncleaned beets, and if these seeds are present in considerable quantity the expense involved in counteracting their distribution over the ground may more than offset the fertilizing value of the water.

SUMMARY OF THE BY-PRODUCTS.

In the following summary of the by-products, as at present utilized, it must be remembered that the returns on which such estimates are based are as yet quite incomplete; hence the figures must be looked upon as only rough approximations. With this understanding, the values previously given are here brought together in the following statement:

Approximate value of the by-products of the sugar-beet industry, 1911–12.

Tops, at $3 per acre	$1,420,000
Dried pulp, at $15 per ton	1,245,000
Wet pulp, at 30 cents per ton	385,580
Molasses, at $10 per ton	1,046,920
Total	4,097,500

COST OF GROWING SUGAR BEETS.

No special effort has been made to collect an exhaustive amount of data upon this subject, but the receipt of many inquiries on the subject has shown a demand for the data presented in Table I. The figures are believed to be both typical and reliable for the places indicated. In the three columns headed "Great Lakes section," the subheadings "Minimum," "Average," and "Maximum" refer to the various column footings and not to any individual items found in the columns.

TABLE I.—*Analysis of the cost of growing an acre of sugar beets.*

Materials and operations.	Great Lakes section.			Intermountain section.		California.
	Minimum.	Average.	Maximum.	Western Nebraska.	Western Colorado.	
Seed	$1.50				$2.40	$1.65
Rental of implements	.55	$2.00				
Plowing	2.00	1.75	$2.00	$2.67	3.00	2.40
Preparation of seed bed	1.00	1.40	4.00			
Harrowing				.80	.75	[1] 1.25
Leveling				.27	1.00	
Rolling				.16		.50
Planting	.40	.40	.50		.75	.35
Cultivating	1.50	3.20	[2] 2.50	[3] 2.00	[1] 2.50	[4] 1.75
Irrigating and furrowing				[5] 2.40	[6] 3.50	3.75
Hand labor	18.00	18.00	20.00			15.45
Thinning and bunching				6.00	6.00	
Second hoeing				2.50	2.50	
Third hoeing				1.50	1.50	
Pulling and topping				10.00	10.00	
Plowing out	1.50	1.75	2.00	2.00	3.00	
Hauling for delivery	5.50	7.00	7.50	9.72	6.60	4.80
Ditch maintenance				2.50		
Total, except rent of ground[7]	31.95	35.50	38.50	42.50	43.50	31.90
Assumed yield per acre ... tons	11	14	12	16.2	11	12
Assumed hauling distance ... miles		2.5		2.5		
Assumed wage, man per day					$2.25	
Assumed wage, man and team, per day				$4.00	$4.50	

[1] Cultivated 3 times.
[2] Cultivated 5 times.
[3] Cultivated 4 times.
[4] Cultivated twice.
[5] Irrigated 4 times and furrowed twice.
[6] Irrigated and furrowed 5 times.
[7] Ground rent, whether cash or shares, is usually reckoned at about one-fourth the delivered value of the crop.

SUGAR PRODUCTION AND CONSUMPTION IN THE UNITED STATES.

Having reviewed briefly the present state of the beet-sugar industry in our country it will be interesting to make some inquiries as to future probabilities and possibilities, as well as to compare our development along this direction with that in Europe. Tables XII and XIII may be taken as a starting point. These tables show the annual consumption of sugar in the United States during the last 25 years, the amount received each year from the various sources, and the percentage contributed by each of these sources, also the yearly per capita consumption and the percentage of the world's crop used in the United States. Without attempting to exhaust the general information obtainable from these tables, attention is directed especially to certain features therein.

Within the past 25 years the total consumption of sugar per annum has considerably more than doubled. This increase has more than kept pace with the increase in population, as is shown by the larger number of pounds used per capita. During this same period the proportion of the world's crop taken by the United States has steadily decreased, from more than one-fourth in 1887 to less than one-fifth in 1911. Of special interest is the fact that during these years the home-grown beet-sugar crop has increased from practically nothing to a point where it has averaged a trifle over one-eighth of our consumption for the past five years. Is it destined to occupy a still larger place in the agricultural economy of the land? For more than 80 years economists have looked forward to a time when we should produce all the sugar needed for home consumption, with perhaps a surplus for export. While we are still far from having reached such a goal, the following figures show how easy it will be physically to do so as soon as the economic conditions therefor shall be ripe.

Present importations from entirely foreign territory now approximate 2,000,000 short tons annually. A home beet-sugar production sufficient to cut off this importation should not affect the home cane-sugar industry adversely, because that has so nearly reached its limit that any possible growth it may have from now on will not equal the annual increase in the country's consumption. With our present low average production of 10 tons of beets per acre and about one-eighth of the weight of beets extracted as sugar, it would require 1,600,000 acres to produce this additional 2,000,000 tons per year. As the acreage harvested last year was a little less than 475,000, it is seen that a total of 2,000,000 acres planted to beets would free us from dependence upon foreign-grown sugar. This round number of 2,000,000 acres makes a very conservative allowance for increased yield due to improved methods and seeds. Table II, compiled from the 1910 census statistics, gives the number of farms, the number of acres of improved land, and the average number of acres of improved land per farm in the States in which it is known that sugar beets can be successfully raised.

TABLE II.—*Number of farms and acreage of improved land in States adapted to growing sugar beets.*[1]

State.	Number of farms.	Improved land.	Improved land per farm.	State.	Number of farms.	Improved land.	Improved land per farm.
		Acres.	*Acres.*			*Acres.*	*Acres.*
California	88,197	11,389,894	129.1	Nebraska	129,678	24,382,577	188.0
Colorado	46,170	4,302,101	93.2	Nevada	2,689	752,117	279.7
Idaho	30,807	2,778,740	90.2	North Dakota	74,360	20,455,092	275.1
Illinois	251,872	28,048,323	111.4	Ohio	272,045	19,227,969	70.7
Indiana	215,485	16,931,252	78.6	South Dakota	77,644	15,827,208	203.8
Iowa	217,044	29,491,199	135.9	Utah	21,676	1,368,211	63.1
Kansas	177,841	29,904,067	168.2	Wisconsin	177,127	11,907,606	67.0
Michigan	206,960	12,832,078	62.0	Wyoming	10,987	1,256,160	114.3
Minnesota	156,137	19,643,533	125.8				
Missouri	277,244	24,581,186	88.7	Total	2,460,177	278,719,622	113.3
Montana	26,214	3,640,309	138.9				

[1] Does not include New York, Pennsylvania, and the New England States, many portions of which are also adapted to growing sugar beets.

An inspection of the footing of the first figure column of Table II shows that if factories were so located that every farmer in these States could plant just 1 acre of sugar beets some of the cane sugar from our noncontiguous territory would have to seek another market. If one farmer in four in these States were to plant a 3-acre patch and give it the care that could readily be bestowed upon so small a plat it would be unnecessary for us to buy foreign sugar. Two-thirds of 1 per cent of the improved land in this area is all that would be required to accomplish this result. More than that acreage lies idle, absolutely unused, every year. Any one of the States of Illinois, Iowa, Kansas, Missouri, Minnesota, Nebraska, or Ohio could produce all this sugar and then have the beets occur only once in a 10-year rotation; several of the others could do it alone on a 5-year rotation.

In Table III the acreage devoted to various crops in the entire country is compared.

TABLE III.—*Comparison of crop acreages, 1911.*

Rank.	Crop.	Acres.	Rank.	Crop.	Acres.
1	Corn	105,825,000	8	Flax	2,757,000
2	Hay	43,017,000	9	Rye	2,127,000
3	Wheat	49,543,000	10	Tobacco	1,013,000
4	Oats	37,763,000	11	Buckwheat	833,000
5	Cotton	36,045,000	12	Rice	696,000
6	Barley	7,627,000	13	Sugar beets[1]	474,000
7	Potatoes	3,619,000			
				Total	291,339,000

[1] Acreage harvested in 1911.

From this table it can be seen that devoting the proposed 2,000,000 acres to sugar-beet production would have an utterly insignificant effect in reducing the acreage of other crops. If they were grown in properly considered rotations with any of these crops except cotton and rice the effect of the beets in increasing the yield of the others would much more than counterbalance the acreage taken from the latter. All that is necessary, so far as acreage is concerned, in order to make us independent sugar producers is to bring the crop to a parity with flax or rye.

A comparison of Table II, showing the improved land in the various beet-producing States, with the acreages reported in Table X will show the proportion of land already devoted to this crop in those States where sugar beets are being grown in the greatest abundance at the present time. Colorado and Utah have nearly 2 per cent of their improved land in beets, Idaho 0.5 of 1 per cent, Michigan and California less than 1 per cent, and Wisconsin about 0.2 of 1 per cent, while the total area for all the States that might be growing them is less than one-sixth of 1 per cent. The German Empire for the 10 years from 1896 to 1905 devoted an average of a little over 1 per cent of its cultivated ground to the crop, while in the Province of Saxony during the same period 4.25 per cent of the soil was given over to it. And they are raising thousands of tons more of other crops now than they were able to produce before they began to grow beets, because of the effect of the beets upon the soil. Their average beet production during this same 10-year period was 13.8 tons per acre for the Province and 12.8 tons for the Empire. The thorough working of the soil necessary for growing profitable beet crops increases the yield of everything else grown on the same ground.

In summarizing this part of the discussion, then, we may say that under stable economic conditions and a knowledge on the part of the farmers of the value of beets in their rotation systems, less than 1 per cent of the available sugar-beet land devoted to the crop would render us as a nation independent of foreign production.

THE SUGAR BEET IN EUROPEAN AGRICULTURAL ECONOMY.

By W. A. Orton,

Pathologist in Charge of Cotton and Truck Disease and Sugar-Plant Investigations.

INTRODUCTION.

Practically one-half of the world's supply of sugar is furnished by the sugar beet. An equal quantity is extracted from sugar cane. The sugar made from the sugar maple, sorghum, palm, and other plants is not enough to be considered in the world's market.

The sugar from cane is of course produced in tropical and subtropical countries. The greater part of the beet sugar comes from central Europe. Germany leads with over 2,800,000 tons annually. Next in order come Russia with 2,250,000 tons, Austria-Hungary with 1,678,000 tons, France with 783,000 tons, Belgium with 312,000 tons, and Holland with 239,000 tons. All these nations produce sugar for export. The United States ranks fifth in this list, with 600,000 tons of sugar from beets, although it stands at the head of the list in the quantity of sugar consumed.

Table IV.—*Production and consumption of beet sugar, with area and yield of the sugar-beet crop of several European countries and of the United States for the year 1910–11.*[1]

Country.	Sugar production.	Sugar consumption.	Area of sugar beets sown.	Yield of sugar beets per acre.	Sugar obtained from beets.
	Short tons.	*Short tons.*	*Acres.*	*Short tons.*	*Per cent.*
Germany	2,854,812	1,406,129	1,169,755	14.84	16.31
Russia	2,324,486	1,462,431	1,614,780	8.93	16.12
Austria-Hungary	1,678,566	641,296	913,159	12.38	14.85
France	783,925	745,610	571,805	10.63	12.90
Belgium	312,196	116,269	150,176	14.53	14.31
Holland	239,073	126,803	122,638	12.96	15.04
United States	510,172	3,611,266	398,029	10.17	12.61

[1] Table IV was compiled from the corrected figures of the International Association for Gathering Sugar Statistics, as published in the American Sugar Industry and Beet Sugar Gazette, January, 1912, p. 24, and February, 1912, p. 21. The column showing "Sugar consumption" was calculated from that published in Licht's Monthly Report, dated Magdeburg, December 9, 1910, and given in Hearings before the Committee on Finance, United States Senate, Sixty-second Congress, second session, on H. R. 21213, 1912, table 5, p. 687.

It will be seen that the culture of the sugar beet plays a very prominent rôle in the agriculture of northern Europe and that it occupies a correspondingly prominent place in the national economy. The industry from its foundation has been fostered by national legislation in every country of Europe. It is thoroughly protected from the competition of the more cheaply produced tropical sugars and is by means of excise taxes made to yield large sums for the support of governments. In Germany the income from sugar taxes from April 1, 1911, to March 31, 1912, reached 170,123,486 marks, or $40,489,000.[1] Europe as a whole derives $200,000,000 per annum from taxes on sugar, yet this is a minor factor in their national economy in comparison with the wealth added by the beet-sugar industry, the money saved by the home production of all the sugar consumed, the receipts from heavy exports of sugar, the employment of many thousands of people, and the indirect agricultural benefits which have accrued from beet culture.

It is primarily the agricultural side of the question with which this paper deals. We shall inquire what the results have been to European farms and farmers from a hundred years of beet culture, and our interest will be quickened by finding at the start that the large acreage required for beet production has not lessened the production of grain and other crops, but that on the contrary a large increase both in total yield and in the average yield per acre has resulted. A considerable portion of this increase is credited to the effects of beet culture, which has become such an indispensable part of European agriculture that it would be continued, in consideration of the indirect returns, even if there were no direct profits from the sale of the beets.

SIGNIFICANCE OF THE EUROPEAN SITUATION TO THE AMERICAN INDUSTRY.

A discriminating study of the sugar-beet industry of Europe and the factors influencing it will help American farmers in two ways. One is by suggesting improvements in methods of culture; the second is by indicating systems of farm management or lines of economic development along which we may advance in the future.

The essential features of European methods of beet culture have already been adopted here. That we shall gain greatly by further direct application of foreign experiences in cultural methods is hardly to be expected. It is undeniable, however, that the general character of our own methods can be greatly improved, but our higher cost of labor and our cheaper land make it probable that advances in the reduction of the farm cost of beets per ton will be made along different lines than in Europe, where land values are very high and labor is very cheap.

It is otherwise with the improvement of our agricultural systems. In this respect we have yet to establish beet culture on a truly permanent basis, and while we can not reproduce in America the conditions of German estates, we shall receive many helpful suggestions from a study of their organization.

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[1] Die Deutsche Zuckerindustrie, vol. 37, No. 17, April 26, 1912.

American agriculture in general has hardly passed its developmental period. We are, however, nearly done with the conquest of new, hitherto untilled territory and must rapidly readjust ourselves to a permanent system of farming. It will be necessary to produce far larger yields per acre of all staple crops in order to feed our increasing population and to give an adequate profit on the cost of intensive cultivation. It will also be necessary to conduct our farming operations in such a manner that the fertility and productive capacity of the soil will not be diminished, but will, on the contrary, be increased from year to year. All these things are possible. They have all been accomplished in other lands and by progressive farmers here. The means by which such problems have been solved and a practicable adjustment of them to American economic conditions constitute one of our large problems for the immediate future. This general betterment of our agriculture will be attained through advances along several lines. Better and more productive varieties will be bred and disseminated, cultural methods improved, fertilizers used more generally and in a rational manner, and plant diseases brought under control; but still greater progress will result from the adoption of improved systems of farm management and business organization.

More attention must be given to the influence on the fertility of the soil of the crops used in rotations, as well as to the production and utilization of by-products for stock feeding.

These points, although long thoroughly appreciated in Europe, have not been understood in this country. Mr. Truman G. Palmer, secretary of the American Beet-Sugar Association, has done more than any one else to point out to Americans the indirect benefits from beet culture. Impressive data which he has collected have been published in congressional documents.[1]

In addition to his very detailed information regarding European conditions Mr. Palmer has tabulated the observations of 115 American farmers who have kept records of their crop yields before and after beet culture. His table, here reproduced, shows remarkable increases in the yields of other crops grown in rotation with sugar beets.

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[1] Beet Sugar. S. Doc. 204, 57th Cong. 1903.

The Beet-Sugar Industry of the United States. S. Doc. 530, 60th Cong. 1908.

The Beet-Sugar Industry as Affecting American Agriculture. Address Delivered at the Twentieth Session of the Trans-Mississippi Commercial Congress, Denver, Colo., August 17, 1909.

Indirect Benefits of Sugar-Beet Culture. S. Doc. 76, 62d Cong. 1911.

Statement of Mr. Truman G. Palmer in Hearings before the Committee on Finance, United States Senate, 62d Cong., 2d sess., on H. R. 21213, 1912, pp. 693-796.

TABLE V.—*Benefits from beet culture to other crops grown in rotation on 115 American farms.*

Crops.	Average yield per acre.				Crops.	Average yield per acre.			
	Before beets.	After beets.	Increase.			Before beets.	After beets.	Increase.	
			Actual.	Per cent.				Actual.	Per cent.
Wheat......bushels..	28.88	43.07	14.19	49.1	Rye..............	......	......	......	39.0
Corn...........do....	41.6	53.1	11.5	27.6	Potatoes...bushels..	151.97	222.2	70.25	46.2
Oats...........do....	40.9	60.6	19.7	48.1	Hay..........tons..	5.7	7.7	2.0	35.0
Barley.........do....	38.97	59.14	20.17	52.0	Beans.....bushels..	15.66	20.26	4.6	29.5

In Europe great stress is laid on the benefit derived from the inclusion in the rotation of a hoed root crop, such as sugar beets, potatoes, or mangels, and the tendency is constantly toward an increased acreage of these cultivated crops and a corresponding reduction in the area occupied by meadow and pasture. The most intensively farmed districts have a larger proportion of their total area under cultivation. Thus, for example, the Province of Saxony has 60.6 per cent of its area tilled ("Acker and Garten"), while the German Empire as a whole has 48.6 per cent, a difference of 12 per cent. It should be noted that the number of cattle kept is increased rather than decreased as the farming becomes more intensive, the by-products from the root crops furnishing forage to replace that formerly grown in meadows and pastures. In the highest development of this system practically all the land is tilled and the cattle are kept the entire year in stables or yards and fed on by-products and purchased concentrates, e. g., beet pulp, beet tops, distillery mash, and straw for roughage, and cottonseed meal, rape meal, peanut meal, and linseed meal, etc., for concentrates.

The German farmer seeks by every profitable means to increase his plantings of root crops. We shall gain by the same practice, and the sugar beet, more than any other crop, will be the one most generally profitable to use, especially north of the corn belt, for the reason that it is the only crop for which we can find a safe, certain, and profitable market for a greatly increased production.

The potato crop stands in the same relation to intensive agriculture as the sugar beet; but it is better adapted to the lighter loams and sandy soils, while the best results with beets are obtained in the heavier soils. Potatoes are more largely planted than other root crops in all northern countries. In Germany their utilization for stock feeding and for industrial purposes, such as the manufacturing of starch, alcohol, and dried potatoes, greatly exceeds the human consumption of this staple. In the United States, until we have similar outlets for surplus production, we can not greatly increase our potato acreage.

Mangels and other roots are extensively used abroad for stock feeding, particularly in Great Britain; but such developments can hardly be expected here, where we have a cheaper substitute in corn silage. The sugar beet remains the only root crop for which a large and certain market can be found. For all localities where soil and climate are suitable for sugar-beet culture this crop promises to play an important rôle in our future agricultural development.

Hitherto sugar beets have been considered by American growers chiefly as an end in themselves. They have been grown for the direct returns derived from the sale of beets for making sugar. In many districts they have been planted more or less continuously on the same land, with a resulting decrease in productivity. There has been a tendency toward specialized beet growing, whereby a few men handled large acreages. Some factories have been forced to engage in the cultivation of beets on a large scale to insure themselves an adequate supply. In the earlier years the pulp was not always in sufficient demand by the farmers and was fed to cattle on the factory grounds or disposed of in other ways that have not returned the fertilizing constituents to the soil. The molasses and lime cake have been an incubus. The leaves and tops have been left on the field or grazed off by cattle owned by another than the beet grower. The result is that up to the present we have not secured the fullest measure of benefit from our beet-sugar industry. This is perhaps the natural condition during the developmental stages of beet culture; but in the present period of transformation and reorganization of our agriculture we should seek to profit from every means for increasing our production and conserving soil fertility.

With due recognition of the fundamental agricultural principles involved and with adequate tariff protection the conditions in the near future will become favorable for a very rapid expansion of the beet-sugar industry in the United States. If this is to be of the greatest good to the country at large, the raising of the beets should not be developed as a specialized business, but should be undertaken in limited acreages by general farmers and in rotations with grain and other crops. The indirect benefits of beet culture can thereby be fully realized.

The United States has such large areas fully adapted to beets that only those districts possessing a favorable soil and climate need attempt to establish factories. Experience shows that beets grown south of the summer isotherm of 70° F. are likely to be deficient in sugar content. Even in the Northern States some communities will develop potato culture and others fruit or truck growing for city markets, while the rougher or mountainous districts will continue stock raising and dairying. In general, however, sugar-beet culture will have its greatest development in our leading agricultural districts along the northern border and north of the corn belt, where there are large areas of fertile loamy soils. It should be noted in this connection that beets thrive with less rainfall than many other crops and are on this account at an advantage in our Northwestern States.

EUROPEAN FARM ORGANIZATION.

In studying the means by which European agriculture has developed yields so greatly in excess of ours and at the same time steadily increased the fertility of their soil we must be impressed first by the more complex business organization of the farm and the systematized planning and interrelationship of the crops. A large German farm presents certain resemblances to a factory. It has its alcohol distillery, where the surplus potatoes are converted into alcohol, an operation which is done on a very small margin of direct profit in consideration of the indirect return which comes from feeding the mash to cattle and the return of their manure to the land. It grows sugar beets for a neighboring factory and often owns a share of this beet factory. The leaves and pulp are all fed to cattle.

In the province of Saxony sugar beets constitute on the average 4.29 per cent of the total area, or 271,900 acres, as compared with 413,000 acres for wheat, 820,000 acres for rye, 378,000 acres for barley, 541,000 acres for oats, and 490,000 acres for potatoes.[1]

Rotations of crops are universal. They vary considerably and are subject to change to suit market and seasonal conditions, but in general beets are not planted oftener on any field than once in three or four years. It appears that the more highly organized and developed the agriculture, the longer the rotations. In earlier times beets were planted oftener and in less developed sections of Europe to-day they are planted more frequently, but this practice has always been disadvantageous. The sugar-beet nematode,[2] an eelworm parasitic on the roots of beets and some other plants, was spread by continuous beet culture. Land became "beet tired" and rotations were forced upon the farmers. Wherever long rotations are now universal the nematode problem has become less serious, and there are only a few fields where beets can not be grown. Oats also are kept off such infected land, as they harbor the nematode.

The danger from this same sugar-beet nematode confronts American growers also. The pest has already been introduced and is present in restricted areas in the West. It will undoubtedly become common unless active measures are taken to combat it. Whether our farmers will profit from the experience of German growers before they are themselves hard hit is a question for the future to determine. We are also likely to suffer from the root-knot nematode, a related parasite producing galls on the roots, especially on the lighter beet lands, though this also can be controlled by a suitable rotation.

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[1] Landwirtschaft und Landwirtschaftskammer in der Provinz Sachsen, 1896–1905, p. 17.

[2] *Heterodera schachtii.*

EFFECT OF BEET CULTURE ON THE PRODUCTIVENESS OF THE SOIL.

That the culture of the sugar beet has played an important rôle in the improvement of European agriculture and that it is to be credited with much of the increased returns from other crops is firmly believed by German writers. We quote, in a free translation from one of the most eminent authorities, Prof. K. von Rümker, of the University of Breslau:[1]

"The high yields which are secured from cereals and other crops in beet localities date from the introduction of rational beet culture, which is therefore the direct and indirect cause of this increase in the gross and net returns of the whole agriculture, and thereby also in the land values in the above-mentioned localities.

"Since the introduction of beet culture, despite a reduction of the acreage of grain, the total grain yield has been increased. It is shown by Briem that since the introduction of beet culture on the estate of Groena in Anhalt there has been harvested from 200 hectares as much grain as formerly grew on 250 hectares. Dr. Lilienthal shows from the books of eight estates in different localities that the introduction of beet culture has increased the yield of wheat 5.95 bushels per acre, the yield of rye 1.59 bushels per acre, the yield of barley 6.51 bushels per acre, and the yield of oats 5.77 bushels per acre. The number of cattle on these eight estates before and after the introduction of beet culture was as 100 to 114.94, the gross income from the cattle before and after is as 100 to 124.80, and the net income of the whole of the agricultural operations in the eight cases is as 100 to 132.22. This difference rises in one case as high as 100 to 170.61.

"As important as was the introduction of clover culture, it does not compare with the progress derived from beet culture on the heavy soils and from potato culture on the lighter soils."

The beneficial effects of sugar-beet culture on general agriculture have been so long established and accepted as a matter of fact in Germany that it is difficult to find any recent experiments bearing on this point.

In years past, however, this question was worked out there with much exactness, by comparison of crop yields on farms before and after the introduction of beet culture and by comparing the results on beet farms with those from adjacent estates where no beets were grown.

Such detailed results are given by Humbert, from whom a single table is quoted from among several given in his book

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[1] Rübenbau und Zuckerkonvention, Berlin, 1903.

TABLE VI.—*Increased yields after beet culture.*[1]

Crops.	Average yield for 10 years—				Net gain in bushels per acre.
	Of 3 nonbeet estates.		Of 6 beet estates.		
	In kilograms per hectare.	In bushels per acre.	In kilograms per hectare.	In bushels per acre.	
Wheat	2,015.00	29.96	2,659.83	39.56	9.60
Rye	1,710.00	27.25	1,898.16	30.25	3.00
Barley	1,550.00	28.81	2,421.66	45.02	16.21
Oats	1,543.33	43.03	2,480.00	69.16	26.13
Peas	1,375.00	20.45	2,107.50	31.34	10.89
Potatoes	12,333.33	183.35	14,583.66	216.85	33.50

[1] Humbert, Gustav. Agrarstatistische Untersuchungen über den Einfluss des Zuckerrübenbau's auf die Land und Volkswirtschaft, unter besonderer Berücksichtigung der Provinz Sachsen, Jena, 1877, p. 46.

The author from whom the above table is quoted emphasizes that on account of the smaller number of nonbeet farms it was the intention to favor them rather than to handicap them. The accuracy of the figures is therefore strengthened by several considerations: (1) The natural quality of the soil was on the whole better on the nonbeet farms than on the farms growing beets. (2) The operating expenses on the nonbeet farms were less in proportion to the income. (3) The management of the nonbeet farms was as rational and the cultivations as intensive as could be found under similar conditions anywhere in Germany. (4) The yields of the products, especially beets reported only from the beet farms, are too low rather than too high.

Humbert summarizes as follows:

"The influence of beet culture, as shown in this summary, is uniformly favorable, stimulating and making more profitable every branch of agriculture.

"The results justify the conclusion that beet culture has been in every way favorable and that it has in many respects exerted the strongest influences upon the agriculture and general prosperity of the fatherland. Its extension has been a source of wealth for whole Provinces. It has been the principal forerunner of intensive agriculture, which has expanded rapidly wherever there are sugar factories.

"The main advantage of beet culture is that it always improves the soil and its harvests, for it permits and even requires a deeper preparation and more frequent cultivation, thorough weeding, and exceptionally heavy fertilizing.

"The yield of every crop is higher on the beet farms than on the nonbeet farms. The total yields of grain are a full third higher in the former, which thus produced and marketed absolutely and relatively more breadstuffs than the nonbeet farms.

"The extension of the area planted to hoed crops requires a more complete utilization of the land available for tillage, it does away with fallowing, and permits a reduction of the area in forage crops, because the by-products from the beet factory and potato distillery are valuable for feeding and enable more live stock to be kept. Although the total number of cattle on the nonbeet farms may exceed those on the beet farms, the latter market more animal products, because their stock is sold sooner and the more liberal feeding results in heavier gains in weight.

"What the distilleries and starch factories are to the light, infertile soils; what stock raising is to the meadows of the fertile coast regions, river valleys, and mountain districts; what vegetable growing is to places with favorable location and soil conditions; all that beet culture has become to the better deeply tillable areas with temperate climate and moderate rainfall."

Later results by Woge fully confirm these conclusions. Table VII gives comparative yields on a German estate for 5 years before beet culture was introduced and for 10 years thereafter.

Woge points out, as did Humbert, that the highest yield of the nonbeet farms is lower than the lowest yield of the beet farms.

TABLE VII.—*Increased yields after beet culture on the Bennigsen estate.*[1]

Crops.	Nonbeet farm, average yield, 1869–1874.		Beet farm, average yield, 1880–1890.		Net gain in bushels per acre.
	In kilograms per hectare.	In bushels per acre.	In kilograms per hectare.	In bushels per acre.	
Rye	1,780	28.36	2,558	40.76	12.40
Wheat	1,650	24.55	2,774	41.25	16.70
Oats	2,214	61.74	2,700	75.30	13.56
Barley	1,248	23.20	2,340	43.50	20.30
Beans and peas	1,868	27.77	4,165	61.93	34.16
Potatoes	14,696	218.50	16,000	237.90	19.40
Rape	1,302	20.74	2,733	43.55	22.81

[1] Woge, Richard. Einfluss des Zuckerrübenbaues auf die Landwirtschaft unter besonderer Berücksichtigung einiger im Fürstenthum Calenberg gelegenen Güter, Leipzig-Reudnitz, 1892, pp. 23–30.

INDIRECT BENEFITS.

Prof. von Rümker[1] thus details the indirect benefits from culture of root crops:

"To grow sugar beets successfully, a deeper furrow is absolutely necessary. This involved the removal of stones and other obstructions to the working of the soil. It also led to the introduction of power plows, which, as is well known, not only do the work more rapidly, but do it more perfectly than team plows. The need for deep cultivation brought about improvements in all soil-working implements and stimulated the manufacture and sale of agricultural machinery. The old types of harrows, rollers, cultivators, drills, etc., suffice no longer. New and better models, adapted to different types of soil and kinds of work, have been developed and introduced. The result of this specialization naturally has been an enormously improved and increased service from these implements, with a corresponding lightening and saving of both animal and human labor.

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[1] Rübenbau und Zuckerkonvention, Berlin, 1903.

"The system of planting in rows was extended to all other cultivated crops. Hand and broadcast sowing was followed quickly by hill and drill planting. Row seeding has the advantage not only of economy of seed and its uniform distribution and depth of planting, securing a quicker and more uniform germination, a more uniform development and ripening, and a larger and qualitatively better harvest, but it makes it possible to rid the fields of weeds and, through cultivation, to keep the soil open and aerated.

"It is thereby possible to influence most favorably the physical condition of the soil, to conserve its water supply, and to promote the activity of the soil bacteria, thereby influencing the fixation of atmospheric nitrogen. In short, the introduction of cultivated crops has proved in physical, chemical, and physiological ways so exceptionally beneficial that the increased cost of production has been paid, and in most cases with good interest.

"The deeper and more carefully one learned to work the soil for the beet crop the greater became the need of more liberal and careful manuring. The development of our knowledge of plant nutrition which followed the work of Liebig was opportune, as it showed how to cheaply and effectively supplement farmyard manure with commercial fertilizers, so that the growth not only of beets, but of all agricultural crops, was improved.

"This development led to a demand for improved varieties of farm crops which would yield better than those previously in cultivation and thereby return a larger profit.

"The laws levying taxes on sugar were fortunately so framed as to encourage the production of beets richer in sugar. Surprising results were accomplished by the method of individual selection based on the polariscope test. A simultaneous improvement of factory methods assisted in increasing the sugar production, so that the weight of beets required to give 1 hundredweight of sugar decreased from the 18 to 20 hundredweight[1] originally needed to 7⅓ hundredweight for Germany in 1901–2.

"The results obtained with beets stimulated work on other crops. The highly bred grains of England were introduced and further improved, until even in the sixties the grain yields of Germany excelled all other countries. Beginning in the early eighties, new and more productive potatoes have been originated, and the higher and more uniform yields of all crops permitted a more effective utilization of the improved cultural conditions resultant from sugar-beet culture.

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[1] In the early years of the sugar industry, in the period from 1872 to 1904, the lowest average extraction was 8.15 per cent of beets. W. A. O.

"These improved varieties were not only more exacting in their requirements as to preparation of the soil, manuring, and planting, but also as to care and protection from unfavorable climatic condition and parasites. Plant diseases and insect pests became more destructive as the agriculture became more intensive, with the result that, in consequence of the efforts made to study and combat them, plant pathology has made great advances; and although it is still only at the beginning of its development, a considerable number of workers are prepared to hasten to the aid of the farmer and assist him in warding off invasion.

"The entire development of our modern intensive agriculture, here only briefly outlined, traces its origin to the building up of a rational sugar-beet industry. From it each department mentioned received the first impulse toward progress, and link by link the chain of improvements was forged, benefiting branches of agriculture which have next to no relation to beet growing. It is consequently no exaggeration to say that the sugar-beet industry was and is the high school of modern intensive farm management."

EFFECT UPON THE LIVE-STOCK INDUSTRY.

"The live-stock side of agriculture and its business organization have also been deeply influenced by sugar-beet culture. The beet farms discontinued the breeding and raising of young cattle and took up dairying and the fattening of beef animals and the production of mutton in place of wool. Between those sections of the fatherland possessing a beet-sugar industry and those without it a division of labor was developed which was advantageous to both sides. The districts where poorer soil or unfavorable climatic conditions prevented the addition of another crop to the rotation grew the live stock, which was later sent to the factory districts to be milked or fattened.

"The large amount of team work done on the beet farms made them the best market for draft oxen, which were supplied from the mountainous districts of Germany where stock raising is the principal industry."

EFFECT UPON THE BUSINESS ORGANIZATION OF THE FARM.

"The farm organization was deeply affected by the beet industry in that the old fixed rotations were given up for a more elastic succession of crops, as in market gardening, retaining the rotation principle only in so far as it appeared physically necessary or financially advantageous. In the main, however, adjustments were made to the state of the market to a much greater extent than before.

"In this way a very important new movement came into force, namely, business planning and accounting. Careful bookkeeping was adopted on the farm, accounts were kept of each branch of the work, mistakes were more quickly discovered, losses were avoided, and profits realized which without the accurate farm balance sheet unquestionably would have been overlooked.

"It should also be remembered that beet culture and the sugar industry enlarge the opportunities for rural employment of a large number of adults and children, and that they have brought about a material increase in farm wages.

"The valuable by-products of the beet field and sugar factory have increased the supply of domestic feeding stuffs to such an extent as to limit the purchases of foreign materials by many millions. Without the pulp, molasses, leaves, etc., it would have been impossible for large numbers of farmers to increase their holdings of live stock to the present extent."

THE BEET INDUSTRY THE FOUNDATION OF MODERN AGRICULTURE.

"The significance of the beet industry as a source of revenue to the State is not treated in detail here, as it might be objected that the State would always obtain the income which it needed and would be indifferent as to the source of the money. Nevertheless, it could not be without value, as a matter of national economy, to maintain a rural industry which increases the tax-paying ability of the country. It is the farming communities which practically constitute our home market, and to maintain their ability to buy and consume is important to the urban industries, especially when foreign countries shall have closed their doors to German exports, an occurrence that will surely take place some day.

"In short, we see from this sketch that beet culture is actually the foundation of our modern intensive and businesslike farm management, that it has not only greatly promoted agriculture, but that it has in large and small, in whole and in part, elevated our whole rural life, promoted stock raising, stimulated farm planning and bookkeeping, improved the intellectual and material conditions of the regions concerned, and contributed indirectly to the welfare of other parts of the country. The sugar-beet industry is the lever that has raised and supported our modern farm management. He who raises the ax against it could strike no more dangerous blow against agriculture, against the possibility of providing our people to the greatest possible extent with home-grown foodstuffs, and against an important part of our national wealth."

Sugar-beet culture is, therefore, a significant factor in our national economy as well as in our agriculture, and on account of its peculiarly beneficial general influence can not be replaced by anything else.

RELATION OF ADAPTATION TO THE IMPROVEMENT OF SUGAR-BEET VARIETIES FOR AMERICAN CONDITIONS.

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INSTANCES OF ADAPTATION.

The adaptation of sugar-beet varieties to our diversities of climate, season, and types of soil would undoubtedly considerably increase our production of sugar. European varieties are bred especially for European conditions, and retain many of their adaptations to the previous environment when brought to America. With some crops such after effects are beneficial, especially the quality of earliness in truck crops, as shown by the popularity of northern-grown seed for early-maturing varieties in southern latitudes, but more often they are a decided disadvantage because they prevent a thorough readjustment to the new conditions. Corroborative proof is shown by the lower average yield from exchange of seed between different localities and the poor quality of southern varieties when grown in the North. In fact, the change may be so violent that the variety fails to fruit, as was observed by the writer when corn from Mexico was grown at Ithaca, N. Y., and when sugar beets were planted in several localities in the United States. Deterioration in yield and quality is common to farm crops when transferred to a decidedly different environment, as shown by the results of variety tests all over the world. Each variety has its own special environment in which it thrives best, and variety tests do not show which is the best variety but merely which gives the best combination of yield and quality in a certain locality. What, then, should we expect when sugar-beet seed bred for a long season and comparatively equable climate, as in the Province of Magdeburg, Germany, is imported annually for both the eastern United States and the dry, irrigated sections of the West? It is no argument to say that several of these varieties are used in various parts of the United States and do about equally well, for they have all been bred for practically one environment and should be expected to exhibit similar behavior. Moreover, they are not all equally valuable for any given locality, as shown by Hans Mendelson, of the Great Western Sugar Co., who found that Klein Wanzleben's Old

Type gives them the highest average results. Obviously, we shall never know our possibilities until we have determined the comparative merits of adapted varieties in each locality having different climatic conditions.

METHODS OF ADAPTATION.

Adaptation is effected by a direct change of type which appears in all individuals alike and is induced by a new environment or by diverse variations accompanied by selection. Cereal rusts are cited by Klebs as an instance of gradual adaptation. When grown in the far North these rusts have a very short period of development; when taken into southern regions they retain this quality for a time but lose it completely in later generations. Duggar[1] states that where corn is introduced from higher latitudes it matures later and later each year and the plants grow taller, thus adapting themselves to the longer season. Lyon[2] experimented with two varieties of corn, Snowflake White and Early Yellow Rose, obtained from western Iowa but grown two years subsequently in central Nebraska. He found that when planted at the Nebraska Agricultural Experiment Station beside the parent stock the corn from Nebraska seed was a foot shorter than the Iowa corn, accompanied by one-tenth reduction in leaf area and a relatively larger ear. Obviously, all these variations were directly adaptive, because there was very little, if any, opportunity for selection. It thus appears that reduced foliage and a relatively large root system, as claimed for sugar-beet varieties adapted to dry areas, may have been acquired by direct adaptation.

The action of new environment in producing variation generally has a tendency toward diversity rather than toward a uniform change in one direction known as local adjustment or place effect. As expressed by Pfeffer,[3] "External conditions act not so much as direct formative, as indirect inducing agents, and thus produce vital changes, leading to an attainment of new hereditary peculiarities." Klebs[4] holds similar views, as he believes both variations and mutations owe their existence to external agents, which, as shown by his experiments, are not always adaptive. Every beet field shows a multiplicity of diverse variations in size, shape, quality, and habit of growth of the various individuals composing it and in the component characters of foliage and root. But since the commercial demand requires a large, rich root, individual plants possessing these qualities are best adapted to the local conditions, economically speaking, and no off plant or rogue should be saved for growing seed.

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[1] Duggar, J. F. Corn Culture. Bulletin 134, Alabama Agricultural Experiment Station. 1905.

[2] Lyon, T. L. Modifications in Cereal Crops Induced by Changes in their Environment. Proceedings of the Twenty-eighth Annual Meeting of the Society for the Promotion of Agricultural Science, 1907, p. 145.

[3] Pfeffer, Wilhelm. The Physiology of Plants [translated by A. J. Ewart], vol. 1, 1900, p. 33.

[4] Klebs, Georg. Studien über Variation. Archiv für Entwicklungsmechanik der Organismen, vol. 24, 1907.

CHARACTERS AFFECTED.

Practically all characters are susceptible to the influence of external conditions. Such characters as size and yield are readily modified by environment, as they are largely dependent upon the food supply and favorable factors for assimilation, but even more fundamental characters as form, structure, and the relative position of parts are also amenable to external conditions, as shown by Stockard,[1] who found that a small excess of magnesium chlorid added to sea water caused the eyes of developing embryos of the minnow, Fundulus, to approach a median plane, giving them the appearance of cyclopean monsters. Herbst [2] also found that by the addition of lithium salts to sea water containing eggs of echinids, he was able to change the whole course of morphogenesis of the larvæ. A similar anomaly was discovered by Babák,[3] who found that tadpoles receiving vegetable nutriment developed an intestine nearly twice as long as when fed on animal food, apparently an adaptation to digestibility. Practically all plants show more or less adaptive growth to external stimuli. If a mesophytic plant grown under semiarid conditions should put forth its usually abundant leafage without a corresponding increase in root system, it would soon die from evaporation; and, likewise, if a xerophytic plant grown in a humid habitat maintained its former size relation between roots and foliage, it would soon be overburdened with water from excessive root pressure. The plant or variety which succeeds best in a new environment is the one which adapts itself most readily. While all plants have this capacity in a certain degree, there are decided limits to which it can extend in a single season, as without doubt the more numerous adaptations come from diverse variation and selection.

INHERITANCE OF VARIATIONS.

Whether variations induced by external agents are inherited is a question of the highest importance to all breeders of plants and animals. Klebs believes that every organism inherits a definite specific structure and within its physiological elasticity fluctuating variations occur, but when the variations proceed beyond the limits of this elasticity they become hereditary. Darwin,[4] though championing natural selection as the chief factor in evolution, was fully aware of the hereditary influence of food and other external agents, for he says: "In my opinion the greatest error I have committed has been

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[1] Stockard, C. R. Journal of Experimental Morphology, vol. 7, no. 2, 1909, p. 285. Cited by Bourne.

[2] Herbst, Curt. Experimentelle Untersuchungen, etc., auf die Entwicklung der Thiere. Zeitschrift für wissenschaftliche Zoologie, vol. 55, pt. 3, 1892, p. 446.

[3] Babák, Edward. Experimentelle Untersuchungen über die Variabilität der Verdauungsröhre. Archiv für Entwicklungsmechanik der Organismen, vol. 21, 1906, pp. 611–702.

[4] Darwin, Charles. Life and Letters [edited by Francis Darwin]. vol. 2, pp. 338 and 408.

[in] not allowing sufficient weight to the direct action of environment, i. e., food, climate, etc., independently of natural selection." Again he says: "There can now be no doubt that species may become greatly modified through the direct action of the environment." It has since been proved repeatedly by experimental evidence. Weismann, Standfuss, Merrifield, and Fischer have all obtained specific hereditary alterations in the color patterns of Lepidoptera by the use of abnormal temperatures. Pictet [1] changed the color pattern of the moth *Ocneria dispar* by feeding the young caterpillars on walnut leaves, their normal food being the leaves of oak or birch. When the first generation was fed on walnut and the second and third on oak, the effects of the walnut were still apparent in the last generation. Pictet experimented with 21 species and 4,965 individuals and in nearly every case some change from the normal type could be directly traced to the influence of the food. Fully as interesting are the experiments of Waltereck,[2] who found that the head of the crustacean Daphnia was broadened by excessive feeding but gradually returned to the original size when the young were restored to the normal nutritive conditions, though the larger size persisted when the overfeeding covered a period of two years. Klebs [3] by controlling external factors was able to induce marked alterations in the floral organs of Sempervivum—double flowers and other aberrations commonly classed as teratological—which were transmitted through seed of the parent. Two species of the fern Asplenium have acquired special morphological characters from growing on serpentine soil, and are classed as distinct varieties. By growing their spores in ordinary soil, Sadebeck [4] found the first generation lost a little of its serpentine character, the second generation a little more, and after five or six generations the character was lost completely. Somewhat similar hereditary deviations have been reported by Strohmer,[5] Briem, and Stift, who claim that the soil not only affects the quantity and quality of sugar-beet seed grown upon it, but all the beets raised from this seed and even those of the second generation.

ADAPTATION AND PRODUCTION.

Whether adaptation arises as a direct response to environment or through elimination of poorly adjusted individuals, it usually leads to increased production. There are some exceptions, possibly from storage of more favorable nutrients in the new seeds, but as a rule such experiments have not been planned to eliminate the effects of breeding and, hence, are not always reliable. Shepperd[1] planted seed wheat grown 1 to 9 years in North Dakota beside wheat of the same parentage brought directly from Minnesota and in 46 trials obtained an average increase of 2.3 bushels per acre in favor of the Dakota-grown seed. From experiments in the Office of Grain Investigations of the United States Department of Agriculture, Warburton[2] found that local seed, in general, "outyields that from a distance, even when the original stock is the same." Lyon[3] found this invariably true for Kherson oats and Turkey Red wheat, and in a similar test with 16 varieties of corn he obtained an average increase of 5.4 bushels per acre from home-grown seed. By placing side by side first-year and second-year plantings of each variety of cotton, Cook[4] invariably obtained higher yields from the second planting, and he believes that the selection of seed for local adjustment would increase the cotton crop 10 per cent. The foregoing experiments show the possibilities of improving the present European varieties of sugar beets for our local conditions by adaptation. The humid sections of the East, the irrigated sections of the West, and even areas where dry farming is practiced should each have their own specially adapted varieties.

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[1] Cited by Morgan, T. H. *See* "Experimental Zoology," 1907, pp. 29-33.

[2] Sonderabdruck a. d. Verhandlungen der Deutschen Zoologischen Gesellschaft, 1909.

[3] Klebs, Georg. Alterations in the Development and Forms of Plants as a Result of Environment. Proceedings of the Royal Society of London, vol. 82, ser. B, No. 559, 1910, p. 547.

[4] Sadebeck, Richard. Berichte über die Sitzungen der Gesellschaft für Botanik zu Hamburg, pt. 3, 1887, p. 74.

[5] Strohmer, F., Briem, H., and Stift, A. The Influence of the Soil on the Seed Production of Sugar Beets. Oesterreichisch-Ungarische Zeitschrift für Zuckerindustrie und Landwirtschaft, 1895, p. 25. Reviewed in Experiment Station Record, vol. 7, 1895, p. 300.

German seedsmen frequently claim that the best variety of sugar beets is the one which maintains its high yield and quality under diverse conditions, but this is not a biological possibility. A variety may be composed of distinct families or strains, each having slightly different powers of adaptation so as to maintain a high average production under certain seasonal variations, which probably is what the Germans mean, but such a variety is not, strictly speaking, a superior cosmopolitan mixture adapted to wide extremes and is only preeminent under certain local conditions.

OUR PRESENT NEEDS AND PROSPECTS.

Obviously the most profitable results would be obtained from American varieties composed of strains highly bred for the climate and soils tributary to each factory, but owing to the concentration of capital necessary for the commercial production of seed the best varieties we can hope for, in the immediate future at least, are those giving the highest average results, either in the direction of maximum percentage or yield of sugar per acre, depending upon the needs of any particular factory, in a general section of the country in which similar climatic conditions prevail.

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[1] Shepperd, J. H. Eleventh Annual Report of the North Dakota Agricultural Experiment Station, 1900, pp. 64-65.

[2] Warburton, C. W. Improvement of the Oat Crop. Circular 30, Bureau of Plant Industry, U. S. Department of Agriculture, 1909.

[3] Lyon, T. L. Loc. cit.

[4] Cook, O. F. Local Adjustment of Cotton Varieties. Bulletin 159, Bureau of Plant Industry, U. S. Department of Agriculture, 1909.

There is no better illustration of a lack of adaptation than the frequent failures of European varieties of sugar beets to produce seed in America. Similar experiences were met during the early history of the industry in Bohemia [1] and Moravia, where sugar-beet breeding was at first a failure. The early breeders came from the vicinity of Quedlinburg and Erfurt and expected to obtain as good results in three or four years as those of old-established firms. Failing in this they attributed the lack of success to climate and soil and claimed the latter was not suitable for seed production. Capable breeders, however, receiving much support from prominent Austrian and Bohemian sugar factories, as shown by the reports of numerous discussions in the conventions, continued to struggle against these difficulties until they attained marked success, which shows that early failures were due chiefly to lack of adaptation.

When we compare the climate of the Province of Magdeburg, Germany, with its long season, relatively cool midsummer weather (mean July temperature below 70° F.), and low humidity, with our short season and hot July weather, it is not surprising that the beets show great diversity in America and fail to produce seed in paying quantities. But if we purpose to rid ourselves of the uncertainty of obtaining seed and wish to build up a truly American industry, we must breed our own varieties of sugar beets and grow our own commercial seed just as France, Germany, and other European countries have done. By making numerous selections from an immense number of seed beets we can hasten adaptation and facilitate breeding.

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[1] Urban, Jos. Die Veredelung der Zuckerrübe. Blätter für Zuckerrübenbau, no. 12, 1909, p. 177.

FARM PRACTICE IN THE ARKANSAS VALLEY, COLORADO.

By L. A. Moorhouse,
Agent, Office of Farm Management.

PHYSICAL CHARACTERS OF THE ARKANSAS VALLEY.

The agricultural region in Colorado known as the Arkansas Valley extends from Canon City to Syracuse, a distance of 200 miles. The river from which the valley takes its name has its source in the mountain range which forms the Continental Divide; the stream, fed from the snow fields to the north and west and emerging from the Royal Gorge, courses in an easterly direction through the valley. The Arkansas Valley in Colorado has an estimated area of nearly 30,000 square miles. More than one-fourth of the State lies in this drainage basin, which includes the southern plains and portions of the eastern slope of the Rocky Mountains.[1] The elevation in this district varies greatly. Canon City, which is located at the base of the range, has an elevation of 5,329 feet; while at Holly, which is well out toward the eastern part of the State, the altitude is only 3,380 feet, a difference of approximately 2,000 feet.

The lands on either side of the river in the valley proper are dependent upon this stream for their supply of water; it is an irrigated country and has been developed through the utilization of these waters. The area which lies beyond the valley in the open plain is used for pasture purposes, although dry farming has been advocated for these lands. Thus far growth in this respect has been somewhat intermittent. The reasons for this feature will be found in the discussions which will be presented in other parts of this paper. Originally the entire country was an open range devoted exclusively to pasture. Gradually small portions of the valley land were brought under cultivation; water was applied through the irrigation ditch; the productiveness of the soil was demonstrated; then more extensive tracts were broken with the plow. Alfalfa grew luxuriantly; the environment appeared to be ideal for this forage plant. Other crops were tested and there was a ready response; thus the country was soon transformed from an open pasture into districts where many farms are being operated.

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[1] Summary of the Climatological Data for the United States, by Sections; Section 7, Region Drained by the Arkansas in Colorado. Weather Bureau, U. S. Dept. of Agriculture.

The past 12 years have witnessed the introduction and development of the beet-sugar industry. The first factory was built at Rocky Ford in 1900. Five other manufacturing plants have since been erected, and the sugar beet has become one of the staple crops of the valley.

CLIMATE OF THE ARKANSAS VALLEY.

The Arkansas Valley is essentially a semiarid district. The average annual rainfall[1] at Holly in the eastern portion is approximately 15 inches. Passing in a westerly direction through the valley, a slight decrease in the precipitation will be observed; at Las Animas the average annual record is 11.65 inches; between this point and the foothills a small increase is noted. The general average for the valley is not far from 12 inches. Fully 75 per cent of the rainfall occurs during the period from April to September. The records of the Las Animas station show that in the average season 4.55 inches of rain falls during the first three months of this period; the summer months give 4.70 inches as an average of many seasons. In the main the greater part of the summer rainfall comes early, and when the showers are heavy the crops are benefited directly. Since so great a part of the rain falls during the spring and summer, it follows that the winter precipitation is exceedingly low. As a matter of fact, the moisture which is available in a normal season does not make any appreciable addition to the stores within the soil. The fields are usually dry and lumpy when they are plowed in autumn, and if winter irrigation is not given they will remain in this condition until spring. A dry surface is not mellowed to any great extent by the frosts of winter. In cases where it is desirable to have the fields in prime condition early the following season, winter irrigation is a necessary step on the part of the farmer; it may not be possible to winter irrigate every farm, but the suggestion is sound, nevertheless.

Owing to the prevalence of fairly strong winds, especially in the spring, some attention must be given to the conservation of the moisture which has been stored within the soil. Careful, systematic tillage will aid in overcoming some of the difficulties which might otherwise interfere with the progress of the farm. Soil blowing must also be controlled as far as possible. Precautionary measures are an outgrowth of a close study of the prevailing climatic conditions. It may be noted as well that high temperatures are common in the valley throughout the summer months, but the dry atmosphere serves to ameliorate the intense heat and for this reason the extremes are not uncomfortable.

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[1] The averages here given are taken from the Weather Bureau report previously cited.

IRRIGATION IN THE ARKANSAS VALLEY.

The most important source of the water which passes down the Arkansas River and its tributaries is found in the snows upon the mountains lying adjacent to their drainage basin. Occasionally, local torrential rains supplement the quantity of water which comes from the melting snow and ice. When such storms do occur, they bring an excessive flow of water, and this excess at times puts many of the smaller streams beyond control. Ditch banks are washed out, headgates are damaged, and crops are destroyed, entailing extra work for repairs and necessitating additional expense. Apart from the points here mentioned, the chief interest of the man who has farming land in the valley under ditch, centers in the quantity of water which comes down the river at various seasons. Measurements have been made and the discharges have been recorded at a few points. Table VIII gives the discharge of the river at Pueblo, Colo., for the 10-year period 1898 to 1907, inclusive, except for certain months as follows: November and December, 1903; January, February, and March, 1904; December, 1906; and January and February, 1907. The drainage area includes 4,600 square miles.[1]

TABLE VIII.—*Discharge of Arkansas River at Pueblo, Colo.*

Month.	Cubic feet per second.			
	Maximum.	Minimum.	Mean.	Per square mile.
January	625	178	370	0.080
February	2,610	150	477	.104
March	775	46	350	.076
April	2,910	95	504	.109
May	11,100	201	1,430	.311
June	6,980	225	2,550	.554
July	5,380	60	1,350	.294
August	8,320	60	730	.159
September	1,370	46	394	.086
October	1,520	31	442	.096
November	1,350	232	436	.095
December	698	178	396	.086
The entire period	11,100	31	786	.171

During the time when these records were made, the maximum discharge occurred in the month of May, while the minimum was reported for the month of October. Snow accumulates at the higher altitudes throughout the fall and winter months. With the increasing temperatures of the spring months, the snow begins to melt; the smaller streams enlarge; and the discharge of the river rises possibly to the maximum. It has been noted that very heavy rainstorms occur at infrequent intervals in the valley. These storms influence the flow of the stream very much at times.

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[1] Compiled from records of the United States Geological Survey, by M. O. Leighton, Chief Hydrographer.

In order to utilize the available water from January to December, provision should be made for the storage of the surplus flow when the streams from the mountains afford an excess due to rapid melting, or when torrential rains coming later in the summer swell the stream beyond its banks. This storage can be accomplished only by turning the surplus into large reservoirs and holding it until a time of need. Then, too, the river furnishes some water during the autumn months; just how far this flow can be used for fall irrigation has not been determined. It is certain that the crop of the following season can be benefited by late fall or early winter irrigation.

SOIL TYPES.

The Arkansas Valley possesses a variety of soil types. These types, for the most part, have a strong retentive power for water, and they contain liberal quantities of plant food, but this fact should not lead the grower to assume that the very best crops can be harvested indefinitely without giving his fields proper care. Planting sugar beets or cantaloupes, or even wheat or oats, for several years in succession upon the same piece of land with no return in the form of manure will undoubtedly throw the soil out of condition, and smaller crop yields will be the direct result. Even though the supply of mineral plant food may seem to be almost inexhaustible, such a course in soil management will consume the organic matter within the plowed surface and will leave the cultivated land defective from a physical standpoint. Organic matter is especially beneficial in these soils. Witness the increased returns through the application of farm manure or the better yields in cases where green manures have been incorporated with the soil. In the many tests that have been made, mineral fertilizers have failed to bring any appreciable response; but farm manure has not left any doubt concerning its value. A part of the increase in yield can, no doubt, be traced to the physical effect of the organic matter of the manure. It improves the texture of the top soil; water enters more readily and is stored more effectively; air also has freer access to the plant roots. If the soil is clayey in nature, humus will make it less tenacious. The operations of the field, particularly cultivation, can under such conditions be done with greater ease. Organic matter not only changes the texture of the soil, affording a more congenial home for the plant, but as it decomposes it acts upon the otherwise unavailable plant food of the soil, thereby placing a larger supply of soluble material at the disposal of the crop.

TYPES OF FARMING.

The cattle range was the starting point for the agricultural industries of the valley. In the beginning, small tracts of land were broken; grain, either wheat or oats, was usually the first crop; then alfalfa was sown, irrigation projects were developed, and a system of general farming was adopted. Alfalfa and grain were the first crops in the rotation. Later, cantaloupes were found to be adapted to the soil and climatic conditions of the valley; thus, a cultivated crop was introduced into the system. Orchards were planted and another type of farming was made possible. The sugar beet was tested and pronounced a success; factories were built, and the farmer had another source of income at hand. After the beet crop was harvested, tops were available for roughage. The supply of pulp was preserved in the factory silo; the broad valley produced abundant crops of alfalfa, and it was natural to find the feeder with herds of cattle and flocks of sheep making preparation to utilize the produce of the land.

In sections where the cantaloupe was grown most successfully, other truck crops were eventually planted. The tomato and the garden pea may be mentioned. The canning industry followed and has experienced a healthy growth. The fame which some of these crops gained, notably the cantaloupe, created a demand for selected seed, and a seed breeders' and growers' association was the outcome. Within the past two or three years other crops have been added to this list; cucumbers are now raised extensively for seed purposes in parts of the valley. Where truck crops are grown, the farms are comparatively small. The poultry industry has been extended on many of these small farms, as well as on the orchard lands. Here in the valley, two farm types have developed, namely, the small farm with its variety of crops, and the large farm with its general crops. Each has its set of problems for solution. Some of these problems are intricate and will require careful study; others are less difficult and it is probable that their solution can be effected quite readily.

MODIFICATIONS IN PRESENT SYSTEMS OF FARMING.

From the statements which have been made it will be seen that the valley produces a very large quantity of roughage, and these foodstuffs when properly combined make an excellent ration either for fattening stock or for other classes of farm animals. During the winter season of 1910–11 large numbers of sheep were fed along the valley of the Arkansas. The following spring there was a slump in prices on the sheep market, and many who were engaged in this work lost money. It was estimated that this loss amounted to $1 per head, or approximately $350,000 for the valley, but in spite of these losses the sheep-feeding business will undoubtedly be continued on an extensive scale for some years to come. The same thing will be true in connection with the feeding of cattle for the block.

Farmers should be interested in plans which will insure against some of these losses. A regular monthly income is preferable to a cash payment which may come once a year through the sale of sheep or cattle or by marketing a crop of wheat. If several crops are grown on the farm, a few of them may be placed directly on the market, while others may be put through a manufacturing process, and a high-priced product can be secured. The salable crops, together with the butter, eggs, or live stock, will provide a regular income for the owner or the tenant. Even if one crop does happen to be short on account of a lack of water at the right time or because a plant disease develops or insects come to check the plants in their growth, the remaining crops ripening at a different period will have a chance to mature and there will not be a total loss. Furthermore, such a system will extend the working season and will give the laborer steady employment from the beginning to the end of the year. It would seem that greater attention might well be given to the dairy industry in the valley. There is a growing demand for the products of this industry within the State of Colorado. Then, too, markets on the outside are not far distant. Each farm could then consume the rough feeds which are raised and the accumulated manure would assist materially in maintaining the yields of the various crops which are used in the rotation. All of these items deserve consideration.

METHODS OF CROPPING.

The variety of crops which are adapted to the soil and climatic conditions of the Arkansas Valley gives the man who wishes to plan a diversified system an opportunity to exercise his skill in working out the details not only for the crops which are to be placed upon the market directly, but provision must also be made for the live stock of the farm. Most of the cropping systems that are in actual operation have a fair proportion of the land in alfalfa, and these fields yield large quantities of nutritious hay. If dairying were to become a part of the farm plan (and it offers several advantages for this section as a whole at the present time), then some changes must be made in the rotations which are now in vogue. In Table IX four rotation plans are given, and from these four a new or suggested fifth plan has been devised, as explained further on.

TABLE IX.—*Arrangement of cropping systems.*

Period.	Rotations.					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	
					Crops.	*Acreage.*
Three to five years	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Alfalfa	One-third.
First year	Cantaloupes.	Wheat	Cantaloupes.	Cantaloupes.	Cantaloupes.	One-sixth.
Second year	Beets	Beets	Beets	Beets or cantaloupes.	Beets	Do.
Third year	Oats or barley.	...do	Cucumbers	Beets	Indian corn.	Do.
Fourth year	Alfalfa	Wheat or barley.	Wheat or barley.	Oats or barley.	Oats or barley.	Do.
Fifth year	...do	Reseeded to alfalfa along with the wheat, the barley, or the oats.				

Rotation 1 has been adopted on a large farm. It is an exception in one respect to the types which follow, and may be classified as a short rotation. Alfalfa is seeded with oats or barley; the field is watered systematically and a strong growth is secured the first season; the following year three or four cuttings of alfalfa hay are taken from the field; the third year brings the alfalfa around to the breaking period and the land is planted to cantaloupes and cucumbers. It is doubtful whether the alfalfa has a chance to make as large crops under this plan as it does where it remains down for a period of three to five years. Alfalfa is essentially a deep-rooted plant, and these roots can scarcely develop fully within so short a time.

Rotation 2 is essentially a grain and sugar-beet system. In sections where the sugar-beet acreage is large this form is sometimes extended, the root crop being repeated for three, four, and even five years in succession. Barley or oats may be sown in place of the wheat as the first crop after breaking the land, and in reseeding the land to alfalfa any of the cereals which have been mentioned may be used. The claim has been made that the very best crops of beets can be harvested after the land has been devoted to this crop for three or more years. The real benefit comes through efficient, continuous tillage, thus placing the soil in proper physical form. There are other phases, however, which should not be overlooked; the advantages of the plan may be overbalanced by the development of disease or through the increase of the insect enemies of the crop. With these checks in view, the grower can not afford to take unnecessary risk. A well-planned rotation should be selected and followed as far as practicable.

Rotations 3 and 4 are almost the same. In the former the sugar beet appears once in the series, while in the latter beets may be grown on the same piece of land for two years in succession. It is also possible in No. 4 to substitute cantaloupes for beets; this gives the root crop only one place in the cycle. Other minor changes can be made readily in either of these forms. The cucumber is grown for commercial seed. It is a crop that will follow alfalfa equally as well as the cantaloupe. Both crops appear to have special adaptations for this place in the rotation; perhaps the date of planting may be the chief reason. The alfalfa roots give some trouble at times, especially with the first cultivations of an intertilled crop, but this difficulty does not seem to be encountered when the cantaloupe or the cucumber is selected as the initial crop in the rotation. Rotations 3 and 4 can be worked out on the small farm just as easily as on the larger tracts. In fact, No. 4 was suggested by a farmer who is cultivating between 20 and 30 acres of land. If necessary, a place can be found for other crops, but some adjustment may have to be made. The canning factory has opened a market for new crops, such as the tomato and the canning pea. On the smaller farms, the grower may not wish to set aside very much land, relatively speaking, for cantaloupes or cucumbers; the sections formerly allotted for the vines can be subdivided, making two additional plats, one for tomatoes and one for peas.

No. 5 is given as a suggested plan; the proportions which are set down under acreage will be used merely to illustrate the rotation which has grown out of the former plans. In applying this schedule to a 40-acre tract, it will be seen that 13⅓ acres are assigned for alfalfa, and 6⅔ acres for each of the other crops in the series. This does not leave any space for the farm dwelling, the outbuildings, or for an orchard and a garden. If 4 acres are assigned for these purposes, the farm plan will stand as follows: 12 acres in alfalfa, 6 acres in cantaloupes, 6 acres in sugar beets, 6 acres in Indian corn, and 6 acres in oats or barley. To rotate the crops will necessitate breaking 6 acres of alfalfa land each year. A similar acreage of land will be seeded to alfalfa annually along with the oats or barley; this will leave each patch of alfalfa intact for two complete seasons. The land which is set apart for cantaloupes may be divided into two or three equal parts, and cucumbers as well as tomatoes may be represented in the truck-crop list. Such a division may insure a more uniform revenue from year to year; when one crop is low in price the others may bring more than an average return.

Indian corn has not been grown very extensively in the Arkansas Valley, but in sections where it has been planted excellent crops have been produced. It should be utilized for supplementary feeding; especially is this true of the farms on which dairy cows are being fed. Corn silage can be combined with alfalfa hay in such proportions as to form a very desirable ration. The beet tops and the beet pulp, if carefully preserved, will provide roughage during the fall and winter months, and the corn silage will serve for spring and summer feeding. The demand for dairy products in Colorado has been constantly growing within recent years; and it would seem that the industry ought to receive some encouragement, particularly in districts where the leading staples have been losing ground. By-products, such as beet tops and beet pulp, which are bringing very little to the grower at the present time, could, under a system of dairy farming, be made to yield a substantial return. More of the alfalfa hay could be fed on the farms of the valley; the supply of available manure would increase; with the application of this material better physical conditions would prevail in the soil types which are being cultivated; and an increase in crop yields would eventually be observed. The industry would also provide continuous work for the farm labor.

THE USE OF MANURE.

In the application of farm manure, or in turning under green manure, two or three points should be observed: (1) The requirements of the crop which is to receive direct benefit should be considered. Land upon which an exhaustive crop is to be planted, if it has been in cultivation for several years, should receive special care. Manure properly applied to such land will influence the returns appreciably. (2) The manure should be scattered at such a time that it will not have a detrimental effect upon the water-holding power of the soil. The work can be done early in the season, at least several weeks and preferably a few months prior to planting. If the manure is incorporated with the soil and water is applied as a winter irrigation, the organic matter will have a chance to decay and to become a part of the soil long before it is time to put in the seed. Under such conditions the capillary movement of the soil moisture will not be interfered with and seed germination should take place readily. Furthermore, this part of the work ought to be done systematically, so that all of the fields of the farm will be treated regularly; where the supply of manure is not adequate, green manuring crops may be grown and plowed under as a substitute for this by-product of the farm. To provide green manure, it will be necessary to modify the rotation so as to make room for the extra crop which is to be utilized for improvement purposes.

TILLAGE METHODS.

In preparing land for the cultivated crops that are common in this part of the State, some of the fields are plowed during the fall and winter months; on other farms spring plowing is the practice. Alfalfa sod is usually broken as soon as the winter season has passed. This work with some consists of two operations: (1) The surface is scalped to a depth of 3 or 4 inches and the field is worked down with a disk harrow; (2) after standing for a few weeks, until the tops are partly decayed, the land is given another plowing. With the second plowing the depth is increased from 3 or 4 inches to 7 or 8 inches. If the supply of water is plentiful and the land is to be planted to vines, the breaking might be postponed a few weeks for the purpose of allowing the alfalfa to grow up and make a partial crop of hay. The field may then be irrigated, and the spring growth can be turned under with the first plowing, which should not be shallower than 6 inches; it is possible that better results can be obtained by turning to a depth of 9 inches. After plowing, the land is brought into suitable tilth by using a disk harrow, the leveler, and the smoothing harrow in turn. Owing to the fact that the rainfall is uncertain, the fields are irrigated prior to planting. A full supply of available moisture brings about prompt and complete germination of the seed; first-class stands are obtained regularly only in this manner. Water is sometimes applied immediately after the seed has been placed in the soil.

THE SUGAR BEET.

The management of land for sugar beets deserves special attention. The factors which aid in securing a large crop are occasionally, if not frequently, overlooked; it is an easy matter to dismiss lightly such work as early, deep plowing, the preparation of an ideal seed bed, thinning for the purpose of obtaining a perfect stand, or gauging the proper amount of water during the growing season. If these things are worked out in detail, and the results are observed by the grower, it is certain that the minor parts in the production of the crop will be carried out at the opportune time. Although a low average yield has been reported for the beet crop in the valley within the past three or four years, a few farms have produced exceptionally good yields; there seems to be good reason for the belief that if excellent returns are possible on small tracts under proper cultural methods, the same methods can be applied on more extensive tracts with corresponding results.

The benefits of deep plowing in the fall or early winter are more readily apparent on lands which are given an irrigation either prior to or immediately after turning. The frosts of winter have very little effect upon a dry surface, and the fields are usually dry after harvest; but if the soil is thoroughly moistened, then the repeated thawing and freezing leaves the surface in a mellow condition. In such a field it is not a difficult task to prepare a suitable seed bed in the spring of the year. The depth to which the soil is plowed governs to some extent the development of the plant roots. In case the soil is heavy and compact, a shallow stirring will give the plant a limited area in which to grow, and a short, stunted root will be produced. This stunting will not only effect a reduction in the yield per acre, but it will also have a bearing upon the composition of the crop. Another decided advantage may be gained by deep tillage: Water can be absorbed rapidly by the soil only where the surface permits a ready penetration; more effective storage will also be afforded under such conditions. The moisture which passes deeply into the soil will return again to feed the growing plant.

Early spring tillage should follow the deep fall or winter plowing. This step is taken in order to conserve the moisture which has been stored in the course of the first irrigation. There is, perhaps, no better implement with which to do the initial work in the spring than the disk harrow. It pulverizes the surface completely and leaves the field in excellent condition for leveling. By repeating this treatment two or three times one may obtain the desired tilth which is characteristic of a first-class seed bed. The next step, planting, involves a careful examination of the planter in order to determine whether it will deliver the required amount of seed regularly. The test may be made by placing some seed in the box; then by setting the planter and driving it over a hard, smooth surface the seed will drop where it can be seen. An examination will show the quantity of seed which is being delivered. If the quantity is sufficient to produce a full stand of plants, the planting may be started in the field. The planter should be watched from the beginning of the operation until the work has been completed. Any defective work will be in evidence at a later time in the season. It may also be stated that straight rows are necessary if the right kind of work is to be done with the cultivator. As soon as the planting has been completed the field is furrowed out for irrigation. Where the land is somewhat rolling in character, or even in a field that is comparatively level, the use of a sled made of small logs will assist materially in getting the first run of water through uniformly.

As soon as the plants are large enough the beets should be thinned to the proper stand. It is customary to block the rows with a hoe, and the bunches which remain are then thinned out so that the stand will approximate one strong plant every 8 inches in the row. The more vigorous plants should be saved in preference to the weak, immature ones; however, if the work is to be done properly, careful supervision must needs be given. It has been suggested that something might be accomplished in the encouragement of better work through the payment of a premium; obviously, low yields can in many cases be traced to poor work in thinning. If a first-class stand of beets is mutilated in the thinning process to such an extent that 25 per cent of the stand has been destroyed, it is almost certain that the final yield will be reduced from a possible maximum almost to the same extent. It is, therefore, highly important that the work be done in accordance with the specified plan.

Throughout the early life of the plant regular cultivation will facilitate growth, and such tillage may, in a measure, take the place of some of the water. Fields are often irrigated and no attempt is made to break up the crust which forms on the surface after the land has dried out more or less; thus, when a second or a third run is made the water can not pass readily into the soil, and crop growth is not stimulated as it should be. More than one advantage can be gained by giving the surface a cultivation at such times. These advantages are shown in the greater storage of water, the better aeration of the soil, and the increased activity of the bacterial life in the soil. The extra growth will pay well for the additional work.

SUMMARY.

To improve the present returns from the beet fields of the Arkansas Valley several fundamental features must be observed. These may be stated in brief:

(1) Fall plowing and autumn or winter irrigation are necessary in the preparation of a first-class seed bed.

(2) A well-planned rotation should be selected, the roughage should be fed on the farm, and the manure should find its way back to the respective fields.

(3) Thorough preparation of the seed bed is essential; early work will assist in retaining soil moisture.

(4) Even, regular planting will insure the stand of beets; the thinning ought to be given careful supervision.

(5) Regular intertillage can not be omitted without incurring losses; care should be exercised in the use of the irrigation water.

LOST MOTION IN THE SUGAR-BEET INDUSTRY.

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INTRODUCTION.

Recently much attention has been drawn to the fact that one of the important sources of economic waste is no less due to a loss, or inefficient application, of motion than to an actual waste or misuse of material.

In many directions studies are being made of the methods of the most rapid and efficient workers to ascertain the factors of such skill. Almost without exception the difference between a workman of this character and a slow, inefficient worker is that the latter generally expends time and energy in unnecessary motions or makes movements that are awkward and indirect. In some industries it has been found that the various operations involved in the manufacture of an article are poorly coordinated, or the machinery badly arranged. It has been found that better system eliminates unnecessary motion, and attention to this point has often made all the difference between profit and loss. For example, Gilbreth, by an analysis of the motions involved in bricklaying, was able to reduce the motions of the bricklayer from 18 to 5, in this way greatly increasing the output of each bricklayer, with less effort to the individual, and the added stimulus of augmented pay. In like manner a close study was made of the methods and motions employed in structural painting. It was found possible so to reduce the movements of the workmen and systematize the method of working that the observant contractor was able to underbid his competitors and still make a good profit. Brandeis offered to show the railroads of this country how they could save $1,000,000 a day. It was chiefly through the elimination of unnecessary motion that he proposed to accomplish this result. The critical study of motion is now being brought to bear on many industries, and has become recognized as an important science in itself.

The fact should be emphasized that the misapplication of motion is equivalent to loss of motion. For example, the application of a little more labor at one point may save a great deal at another, or may result in a yield so much greater that it would far more than compensate for the additional labor.

Is it not possible that a scrutiny of agricultural methods will reveal losses of motion? As a beginning, let us make a brief survey of the sugar-beet industry. Under what have hitherto been the most favorable conditions the sugar beet is a comparatively costly crop to raise, owing chiefly to the fact that intensive methods must be employed to insure success. Some of the points discussed may perhaps apply to other crops as well.

EXAMPLES OF LOST MOTION.

Loss of material and motion in the application of manure.—In the preparation of the soil for the beet crop it is observed that the practice of hauling manure during the winter and at odd times and dumping it in heaps here and there over the fields is still quite general. Later these piles of manure are scattered with forks. This practice is distinctly wasteful of motion and material. Almost twice as much labor is involved as would be necessary to scatter the manure broadcast directly from the wagon, even though done with forks. A much greater saving of motion would be effected through the use of manure-spreading attachments on the wagons. The labor thus saved in one season on a farm of moderate size would be enough to cover the additional cost of a manure spreader, for labor is costly in this country. The practice of dumping the manure in heaps (Pl. III, fig. 1) and leaving it thus for an indefinite time is bad; rains leach much of the valuable constituents of the manure into a very small patch of ground. In this spot beet seedlings may be killed, or if they survive they may be overstimulated and produce too much foliage and a low sugar content. In addition, manure thus applied is usually quite irregularly distributed. If the manure can not be applied broadcast at once, it would be much better to conserve it in bulk, with provision to save the leachings.

Inefficient method of blocking and thinning.—Blocking and thinning is a costly operation as at present practiced. There is yet no prospect of avoiding hand labor to thin beets, but it is believed that the blocking might much better be done with suitable machines. It could be done with greater exactness and far more rapidly with a machine than by hand. It is at times almost impossible to get the necessary labor for blocking and thinning beets, thus delaying the operation and causing a loss of yield. Several machines have already been invented to perform this operation, and if they are found to be practical implements they should be brought into general use. The objection is frequently raised that a machine will not discriminate, that it will cut out many of the few remaining plants in spots where

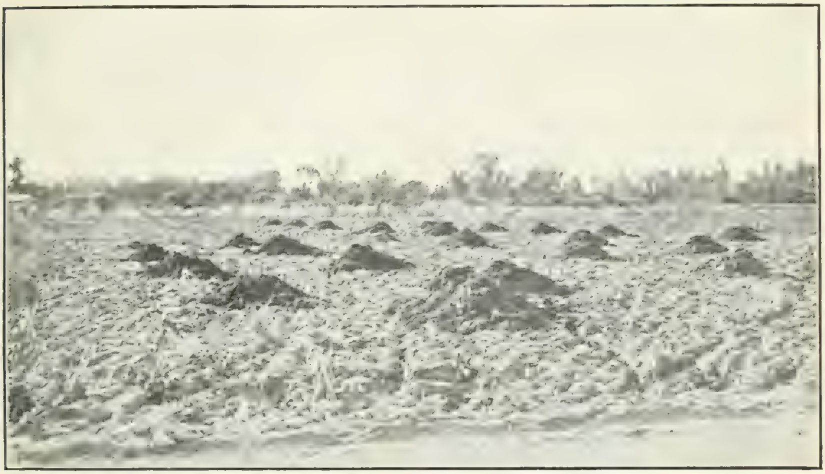


FIG. 1.—FIELD SHOWING MANURE DEPOSITED IN SMALL HEAPS TO LIE FOR MANY WEEKS BEFORE BEING SPREAD.

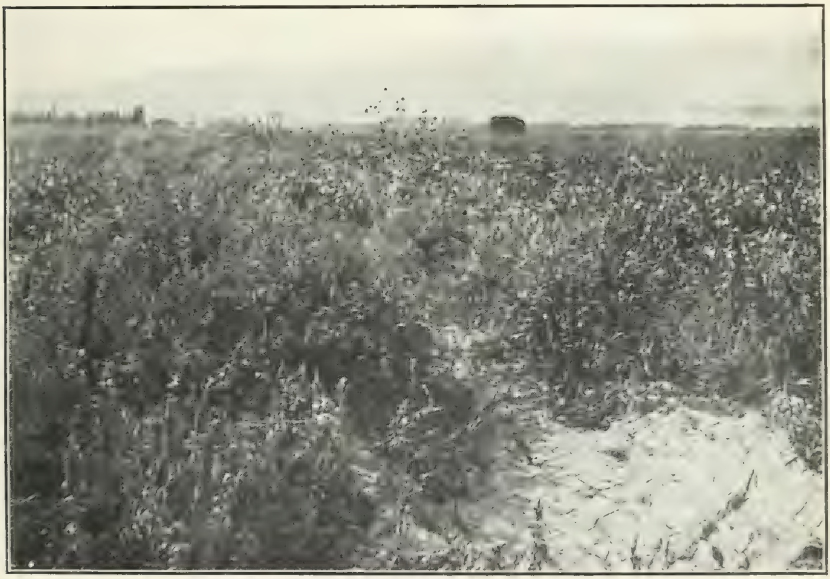
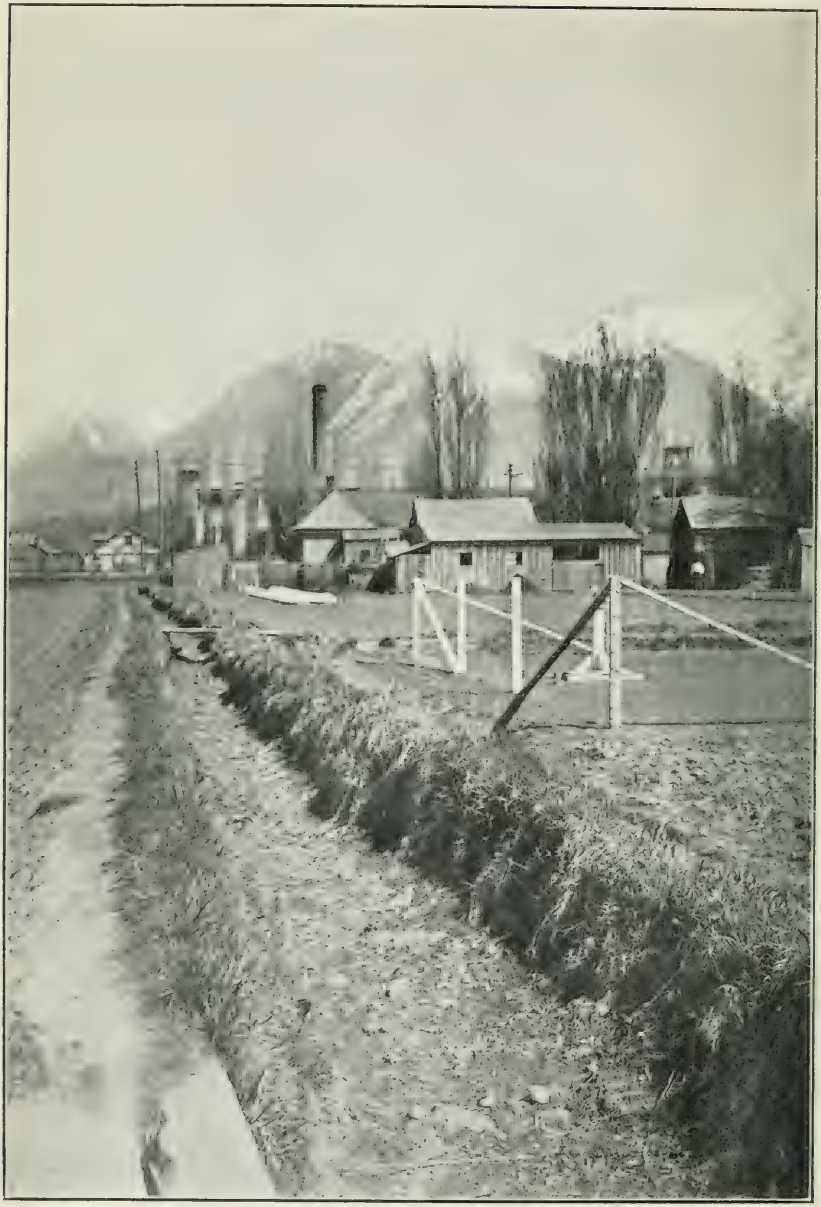


FIG. 2.—IRRIGATION DITCH ALMOST OBSCURED BY GROWTH OF WEEDS.



PERMANENT LATERAL IRRIGATION DITCH WHOSE BANKS ARE KNIT TOGETHER WITH GRASS; EASILY KEPT FREE FROM WEEDS.

the stand is poor, thus leaving a gap of varying size in the row whereas the laborers who perform this operation by hand would leave such plants, although they might be irregularly spaced. Granting that this unevenness of stand sometimes happens, it is believed that few beet growers realize how far short of the theoretically correct number of beets are left in the field, even when the stand is practically perfect to start with, after the blocking and thinning have been done by the ordinary hand methods. Especially is it so when no real supervision of this work is provided for. This is one of the most important operations so far as the tonnage of the crop is concerned, but it is too often very carelessly done. To the writer's knowledge blocking machines have been tried, but because some gaps have occasionally been left in the manner already indicated it has been concluded that it would not pay to continue their use. It is believed that such a conclusion is not founded on correct knowledge. A few gaps in the rows here and there would not reduce the total number of plants to anything like the extent that even the ordinary hand blocking and thinning does. A perfect stand would be represented by a plant every 8 inches in the row. On this basis the best stand left after thinning that the writer has been able to discover equaled 88 per cent of the perfect one, while the ordinary field, even among good beet growers, does not grade much better than 50 per cent of a perfect stand. The field showing 88 per cent was blocked and thinned by the owner himself, who is a successful truck farmer. The difference in tonnage between this field and the acreage for the locality was very marked. Furthermore, the introduction of machine blocking should stimulate the growers to greater effort to secure perfect stands. This result may frequently be accomplished by more care in the preparation of the soil for seeding—very often the soil is left far too lumpy.

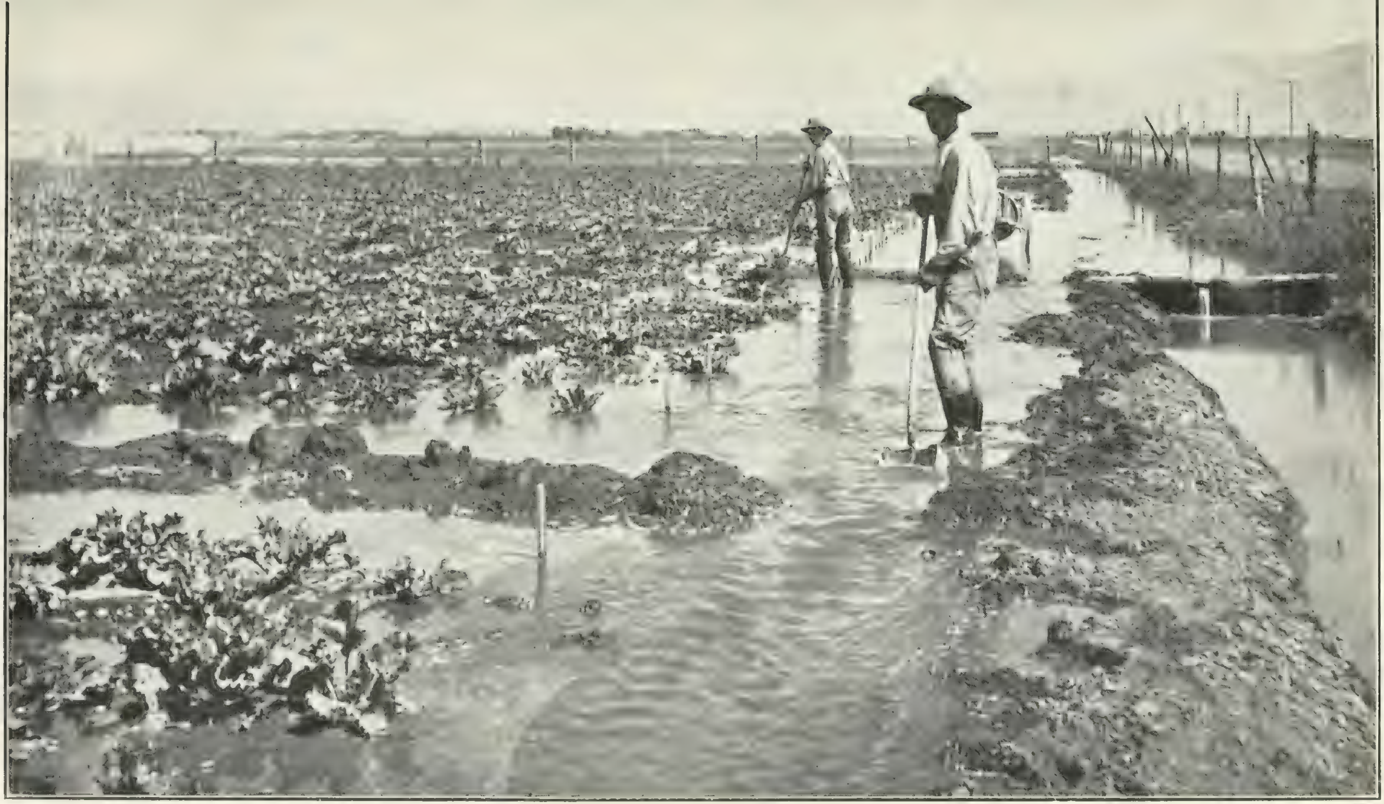
Weeds.—A great deal of the weeding can be done with horse weeders and cultivators. In the irrigated beet districts too much motion is applied in one direction through the lack of a little in another. It is a common and decidedly bad practice in these irrigated districts to pay practically no attention to weeds along banks of ditches and laterals; also along watercourses supplying the ditches. (Pl. III, fig. 2.) The weeds shed their seeds into the ditches, where they are carried along and finally spread broadcast over the fields with every irrigation. Further, the weeds harbor many kinds of injurious insects. The labor involved in cutting these weeds just before they mature their seed, perhaps twice during a season, would be far less than that now involved in ridding the fields of the weeds carried there as seed by the irrigation water. It would be still better to sow some forage crop along the banks of watercourses to bind the soil and protect the banks as shown in Plate IV. The labor of mowing the banks would be amply repaid by the forage yield.

Irrigation.—It is well known in the irrigated areas that one essential for the proper and economical application of water is that the surface of the fields should be as smooth as possible and free from undulations, especially across the line of water flow; it should have a grade suited to a steady, even flow of water, and the ditches or laterals should be carried to the highest points in the field. Frequently the writer has seen portions of a field adjacent to the ditch lower than portions some distance away. This necessitated the construction of temporary levees or ridges at every irrigation to carry the water across, and resulted in flooding the lower tract adjacent to the ditch. A little more labor with a float or light scraper would have permanently removed this source of waste motion. (Pl. V.)

Harvesting.—Another costly operation incident to beet growing is that of harvesting. A really successful beet topping and harvesting machine is much to be desired. Several such machines have already been devised both in this country and in Europe. Some of them promise, with minor improvements, to meet the needs.

At present practically all the operations of pulling, topping, and loading are done by hand. But even so, it does not appear that everywhere the best methods of hand labor are employed. The most systematic and rapid method with which the writer is acquainted is as follows:

In general a two-horse beet digger or lifter is used; with this machine the beets are thoroughly loosened and lifted almost out of the ground. The laborers then throw 7 to 9 rows of beets into one windrow; advancing up the rows and handling two or four rows at once, they throw the beets upon the middle row so that the roots shall all lie in one direction; they then return down the other side of the central row and throw the beets from four rows on that side. (Pl. VI, fig. 1.) Next, taking beet knives heavy enough to sever the crown at one stroke, but not too heavy to handle without fatigue, they start at one end of the windrow, kneeling or stooping, and follow to the other end. Instead of dropping the beets in a continuous row, however, they throw them into a pile in advance; as the pile is reached another is started, and so on. This leaves a series of beet piles ready for loading. Should it not be possible to haul the beets immediately, it would pay to cover each pile of beets with the leaves, thus preventing loss of weight through evaporation. This method has the advantage that the tops are left in compact windrows convenient for hauling to a silo, or for feeding fresh to stock. In some localities the toppers follow each single row of beets; standing erect most of the time, they stoop and pick up the beets by jabbing them



FIELD OF BEETS UNDER IRRIGATION, SHOWING LOCATION WHERE LABOR IS REPEATEDLY LOST DURING EACH SEASON THROUGH LACK OF A LITTLE ADDITIONAL GRADING.

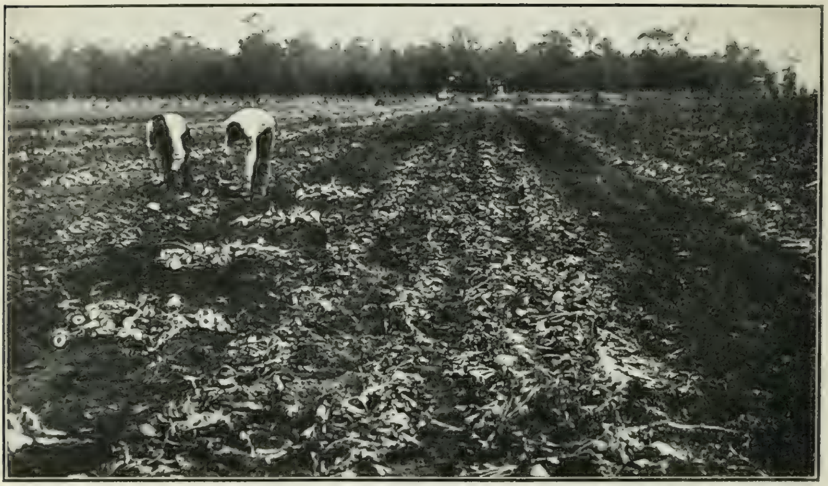


FIG. 1.—FIELD OF BEETS IN MICHIGAN, SHOWING A GOOD SYSTEM OF PULLING AND TOPPING BY HAND.

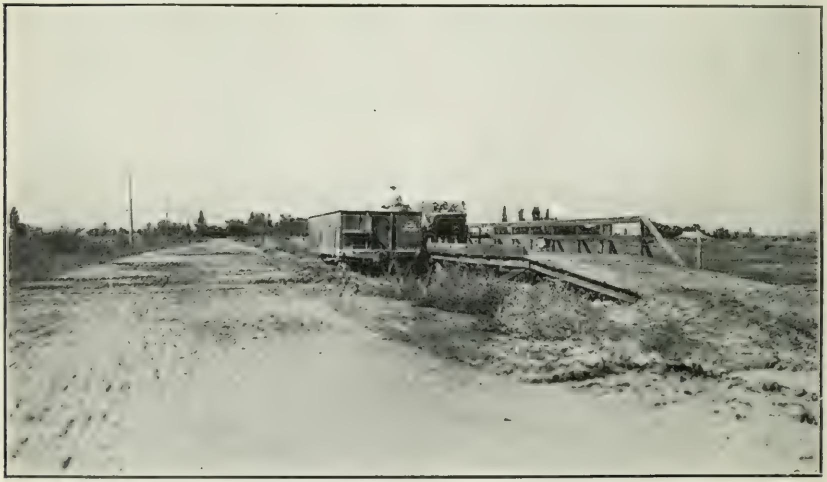


FIG. 2.—A POOR TYPE OF LOADING STATION. THE BEETS MUST BE LOADED IN RAILROAD CAR WITH FORKS.

with a heavy knife having a sharp beak at the tip; with the left hand the beet is then seized and removed from the knife beak and topped with the right hand; the beets as they are topped are thrown in small heaps. (Pl. VII.) This method appears to the writer to be much inferior to the other. The beaked knife is a dangerous tool; accidents have occurred in which the workman's leg has been seriously injured. There is a great amount of lost motion in stooping from the erect posture, straightening up again, and seizing the beet from the knife. Although this method does not require the pulling and throwing of the beets into windrows, that feature is equalized by the greater number of times the man must cross the field when taking but one row at a time. The probable loss of motion and of time is about 25 per cent.

Roads.—An extensive literature on the subject of roads is already in existence. The bulletins and circulars of the Office of Road Inquiry, Department of Agriculture, are available and give ample detailed information. The need of road improvement is a crying one. This fact is especially apparent in many of the more sparsely settled Western States. Roads generally are much wider than is necessary or desirable; a wide strip is left unused on either side and becomes a breeding place for weeds and injurious insects. It has been proposed, and in at least one State put into practice, to cultivate these roadside strips and raise upon them some profitable crop. On the roadsides in many parts of Europe the much narrower strips are covered with greensward and planted with fruit trees that are a source of profit to the communities in which they are grown. Most of our country roads are, much of the time, badly rutted, exceedingly dusty in dry weather, and almost indescribable, owing to mud, in wet weather. As compared with a good, hard-surfaced road it has been calculated that only about one-half as much can be hauled by the same team on these bad roads as would be practicable on good ones.

It is practicable to make fairly good dirt roads, but to do so it is necessary to make liberal use of good, heavy rollers. Only too commonly it is the practice simply to scrape or grade the dirt toward the middle of the roadway, and, after smoothing it off, leave it entirely without rolling. Within a few days the loose dirt becomes deeply rutted. It would be a great improvement to put broad tires on all wagons and to make the axles of the hind wheels longer than the front ones, so that the two pairs of wheels would not track. Such tires would not only prevent cutting ruts, but would actually consolidate the roads in a manner similar to the work of rollers; furthermore, hauling is much easier over indifferent roads with broad than with narrow tires. "The Missouri Agricultural Experiment Station made a series of tests extending from January, 1896, to September, 1897, in order to thoroughly and scientifically ascertain the value of wide tires as compared with narrow ones. They were made with two wagons, one with 6-inch tires, the other with standard 1½-inch tires, both wagons of the same weight, and each loaded with 2,000 pounds. It was found that the same power needed to draw the narrow-tired wagon, with its 2,000-pound load on a gravel road, would have pulled a load of 2,482 pounds on the wide-tired wagon. The same power required to draw the 2,000-pound load on narrow tires over dirt and gravel roads when they were dry and hard was found sufficient to draw a 2,530-pound load on the wide-tired wagon under the same conditions; and it was shown that when these roads were deep with mud but partly dried at the surface by a few hours' sun the same power required to draw the 2,000-pound load over them on the narrow tires would pull a load of 3,200 pounds on the wide tires."[1] It is practicable to clamp wide tires on the narrow-tired wheel. It has been conservatively estimated that the annual loss to this country through bad roads is not less than $500,000,000.

Beet dumps.—Badly constructed beet dumps cause great loss of motion. It is highly probable that there are no beet districts wherein some of the farmers are not obliged to ship their beets by rail or water after hauling them to a loading place. This at best means a double handling of the crop. Only too often the loading or dumping station, as it is called, is merely a grade running up to a low platform. (Pl. VI, fig. 2.) The wagon is hauled upon the platform, thus bringing the top of the wagon to about the level of the top of the railroad car. The beets must then be forked from wagon to car—a slow, laborious operation. The grade should always be such as to carry the wagon above the car, so that the beets may be dumped in bulk from endgate or hinged side directly into the car. The farmers should be in a position to demand properly constructed loading platforms. It would even pay them to construct them at their own expense, if necessary. At the factory this matter is greatly emphasized. (Pl. VIII, figs. 1 and 2.) All beet sheds should be so constructed that the beets may be dumped from wagon and car in bulk. The practice of dumping beets in great piles at loading stations is very wasteful of motion and should by any possible means be avoided. The management of loading stations and factory bins should be so organized as greatly to reduce the necessity for the farmers to wait in line to dump their beets. Instances have come to the writer's knowledge where hours have been thus wasted. Sometimes the railroads are guilty in failing to furnish sufficient cars to keep the beets moving. So also should the practice be less frequent of com-

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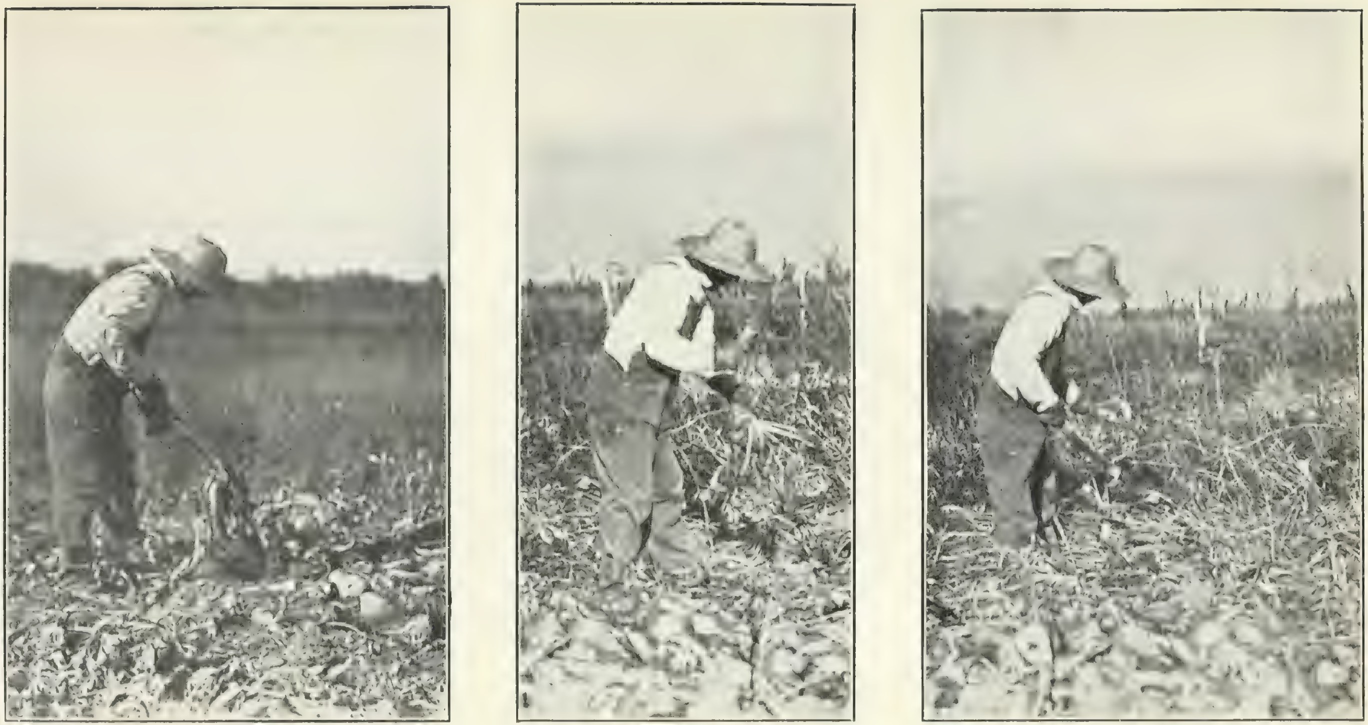
[1] Circular 31, Office of Road Inquiry, U. S. Dept. of Agriculture, pp. 35-36.



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TOPPING BEETS WITH A BEAKED KNIFE, A METHOD INVOLVING MUCH LOST MOTION AND DANGER TO THE WORKMAN.

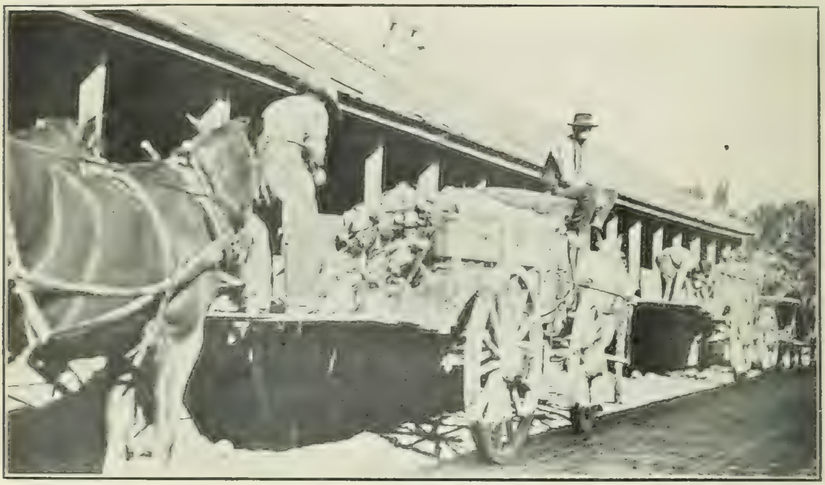

FIG. 1.—WAGONS TO BE UNLOADED WITH FORKS.

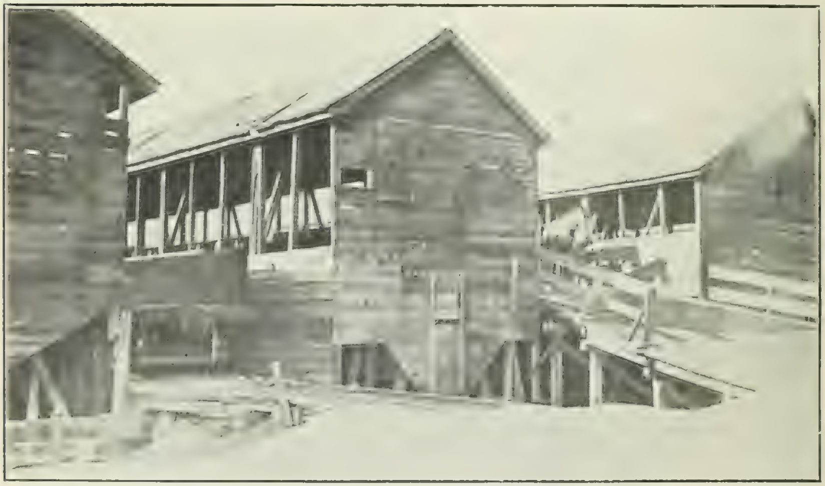

FIG. 2.—RAILROAD CAR TO BE UNLOADED WITH FORKS.

POOR TYPES OF BEET SHEDS.

pelling the farmer to silo his beets in the field because the factory can not take care of them as fast as delivered. There should be shed accommodation in proportion to the capacity of the factory and the probable supply of beets, except in case of unusual emergencies. To be sure, the farmer, when called on to silo part of his crop, receives some compensation for the extra labor involved but none for the loss in tonnage through drying of the beets. The industry is founded on the cooperation and good will of the growers. They should receive every reasonable consideration.

These instances are not imaginary ones or at all uncommon. On the contrary, they are rather widespread. A recognition of them may be a step toward their removal or reduction, with a consequent saving of motion, time, and money.

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SUGAR STATISTICS.

On the following pages will be found several tables of statistics relating to the sugar industry. Statistics for which the sources are not otherwise indicated have been compiled in this office from data obtained by special correspondence with the factories and growers.

As the usual annual report of the department upon the beet-sugar industry did not appear last year, the full crop statistics of 1910 for the several States are here reprinted. These statistics, made up from data collected by the department, were published in the Crop Reporter for October, 1911.

TABLE X.—*Beet-sugar crop in the United States.*

FOR THE YEAR 1910-11.[1]

State or year.	Factories.		Area harvested.	Yield.	Value per ton.	Beets worked.	Analysis.		Sugar manufactured.	Recovery.		Loss of beets.
	Number.	Run.					Sucrose.	Purity.		Beets.	Sucrose.	
		Days.	*Acres.*	*Short tons.*		*Short tons.*			*Short tons.*	*Per cent.*	*Per cent.*	*Per cent.*
California	8	114	90,500	10.20	......	923,100	18.20	82.78	139,890	14.18	77.90	4.02
Colorado	13	63	81,412	10.62	......	864,474	15.19	83.40	103,092	11.92	78.50	3.27
Idaho	3	53	13,178	8.39	......	110,556	16.82	87.38	14,269	12.91	76.75	3.91
Michigan	17	100	117,500	10.28	......	1,207,700	16.08	86.15	139,215	11.53	71.70	4.55
Utah	5	82	26,767	11.42	......	305,773	15.80	85.71	38,490	12.59	79.65	3.21
Wisconsin	4	76	16,772	9.14	......	153,327	16.75	84.14	18,130	11.82	70.60	4.93
Other States	11	68	51,900	9.29	......	482,362	15.66	82.69	57,086	11.84	75.59	3.82
Total or average	61	83	398,029	10.17	......	4,047,292	16.35	84.35	510,172	12.61	77.10	3.74

FOR THE YEAR 1911-12.[2]

State or year.	Number.	Run.	Area harvested.	Yield.	Value per ton.	Beets worked.	Sucrose.	Purity.	Sugar manufactured.	Beets.	Sucrose.	Loss of beets.
California	10	98.5	99,545	10.42	5.54	1,037,283	18.95	......	161,300	15.55	82.04	3.40
Colorado	14	63.3	86,437	11.07	5.55	957,142	15.44	......	124,800	13.04	81.22	2.40
Idaho	3	91	17,052	12.11	5.02	206,367	16.65	......	26,730	12.95	77.80	3.70
Michigan	17	122	145,837	9.90	5.74	1,443,856	14.59	......	125,500	8.69	59.55	5.90
Utah	6	96	33,950	13.03	4.81	442,310	15.98	......	57,280	12.95	81.04	3.02
Wisconsin	4	106	23,241	11.02	5.51	256,124	14.23	......	23,640	9.23	64.86	5.00
Other States	12	83	67,815	10.61	5.48	719,251	15.16	......	80,250	11.16	73.60	4.00
Total or average	66	94+	473,877	10.68	5.50	5,062,333	15.89	......	599,500	11.84	73.92	4.05

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[1] From the Crop Reporter for October, 1911, except the percentages of sucrose and loss, which are computed.

[2] Compiled in the office of Cotton and Truck Disease and Sugar-Plant Investigations.

TABLE X.—*Beet-sugar crop in the United States*—Continued.

ANNUAL STATISTICS FOR 11 YEARS, FROM 1901-2 TO 1911-12.

State or year.	Factories.		Area harvested.	Yield.	Value per ton.	Beets worked.	Analysis.		Sugar manufactured.	Recovery.		
	Number.	Run.					Sucrose.	Purity.		Beets.	Sucrose.	Loss of beets.
		Days.	*Acres.*	*Short tons.*		*Short tons.*			*Short tons.*	*Per cent.*	*Per cent.*	*Per cent.*
1901-2	36	88	175,083	9.63	$4.50	1,685,688	14.8	82.20	184,605	10.95	74.00	3.85
1902-3	41	94	216,400	8.76	5.03	1,895,812	14.6	83.30	218,406	11.52	78.90	3.08
1903-4	49	75	242,576	8.56	4.97	2,076,494	15.1	......	240,604	11.59	76.75	3.51
1904-5	48	78	197,784	10.47	[1] 4.95	2,071,539	15.3	83.10	242,114	11.69	76.42	3.61
1905-6	52	77	307,364	8.67	[1] 5.00	2,665,913	15.3	83.00	312,920	11.74	76.74	3.56
1906-7	63	105	376,074	11.26	[1] 5.10	4,236,112	14.9	82.20	483,611	11.42	76.65	3.48
1907-8	63	89	370,984	10.16	[1] 5.20	3,767,871	15.8	83.60	463,628	12.30	77.84	3.50
1908-9	62	74	364,913	9.36	[1] 5.35	3,414,891	15.74	83.50	425,884	12.47	79.22	3.27
1909-10	65	83	420,262	9.71	......	4,081,382	16.10	84.10	512,469	12.56	78.02	3.54
1910-11	61	83	398,029	10.17	......	4,047,292	16.35	84.35	510,172	12.61	77.10	3.74
1911-12	66	94	473,877	10.68	5.50	5,062,333	15.89	......	599,500	11.84	73.92	4.05
Average:												
1901-2 to 1905-6	45.6	82.4	227,841	9.13	......	2,079,089	15.02	82.90	239,730	11.53	76.78	3.49
1906-7 to 1910-11	62.8	86.8	386,052	10.13	......	3,909,510	15.78	83.55	479,153	12.26	77.84	3.52
First 10	54.2	84.6	306,947	9.75	......	2,994,300	15.40	83.27	359,441	11.90	77.28	3.50

[1] S. Doc. 22, 61st Cong., 1st sess.

TABLE XI.—*Beet-sugar crop in Canada.*[1]

Crop of 1911-12.		Sugar production, 1904-5 to 1911-12.			
Data covered.	Amount.	Year.	Yield.	Year.	Yield.
			Short tons.		*Short tons.*
Harvested ... acres	12,000				
Beets handled ... short tons	95,520	1904-5	9,000	1908-9	7,800
Yield per acre ... do	7.96	1905-6	12,800	1909-10	9,860
Sugar manufactured ... do	10,700	1906-7	12,730	1910-11	8,700
Recovery, beets ... per cent	11.20	1907-8	8,900	1911-12	10,700

[1] Statistics for 1911-12 are based in part on direct reports from the factories and in part on estimates in Willett and Gray's Weekly Statistical Sugar Trade Journal for April 3, 1912. The statistics of production for 1904-5 to 1911-12 are from the last-mentioned source.

TABLE XII.—*Commercial cane and beet-sugar production of the world, 1812-1911.*[1]

Year.	Total.	Cane.	Beet.	Cane.	Beet.	Year.	Total.	Cane.	Beet.	Cane.	Beet.
	S. tons.	*S. tons.*	*S. tons.*	*P. ct.*	*P. ct.*		*S. tons.*	*S. tons.*	*S. tons.*	*P. ct.*	*P. ct.*
1812-13	....	....	3,849	......	......	1859-60	1,875,234	1,446,274	428,960	77.1	22.9
1836-37	....	....	40,777	......	......	1860-61	2,062,215	1,675,815	386,400	81.3	18.7
1840-41	1,288,000	1,232,000	56,000	95.65	4.35	1861-62	2,246,974	1,793,374	453,600	79.8	20.2
1850-51	1,568,000	1,344,000	224,000	85.8	14.2	1862-63	2,177,496	1,664,536	512,960	76.4	23.6
1853-54	1,591,025	1,365,905	225,120	85.9	14.1	1863-64	2,094,023	1,605,703	488,320	76.7	23.3
1854-55	1,547,635	1,347,155	200,480	87.0	13.0	1864-65	2,193,422	1,587,502	605,920	72.4	27.6
1855-56	1,583,119	1,317,679	265,440	83.2	16.8	1865-66	2,429,136	1,667,536	761,600	68.6	31.4
1856-57	1,690,319	1,410,319	280,000	83.4	16.6	1866-67	2,265,096	1,543,816	721,280	68.2	31.8
1857-58	1,861,723	1,456,283	405,440	78.2	21.8	1867-68	2,536,656	1,832,428	704,228	72.3	27.8
1858-59	2,120,724	1,691,764	428,960	79.8	20.2	1868-69	2,501,105	1,775,546	725,559	71.0	29.0

[1] Statistics for 1812-13 are from report of the minister of the interior of France; for 1836-37, from Jules Helot's "Le Sucre de Betterave en France," 1800-1900, p. 209; for 1840-1851, from Monthly Summary of Commerce and Finance, February, 1901; for 1853-1904, from Special Reports of the Census Office; Manufactures, pt. 3, 1905 (issued 1908), p. 451; for 1904-1912, from Willett and Gray's Weekly Statistical Sugar Trade Journal. Data for 1905-6 and succeeding years include production for British India, while exports are reported for other years.

TABLE XII—*Commercial cane and beet sugar production of the world*—Contd.

Year.	Total.	Cane.	Beet.	Cane.	Beet.
	S. tons.	*S. tons.*	*S. tons.*	*P. ct.*	*P. ct.*
1869-70..	2,794,720	1,861,708	933,012	66.6	33.4
1870-71..	2,830,452	1,791,436	1,039,016	63.3	36.7
1871-72..	2,970,741	2,008,125	962,616	67.6	32.4
1872-73..	3,321,168	2,061,904	1,259,264	62.1	37.9
1873-74..	3,200,527	1,917,174	1,283,353	59.9	40.1
1874-75..	3,272,659	1,967,482	1,305,177	60.1	39.9
1875-76..	3,408,999	1,895,968	1,513,031	55.6	44.4
1876-77..	3,098,223	1,884,435	1,213,788	60.8	39.2
1877-78..	3,487,985	1,921,808	1,566,177	55.1	44.9
1878-79..	3,937,097	2,201,909	1,735,188	55.9	44.1
1879-80..	3,734,380	2,131,714	1,602,666	57.1	42.9
1880-81..	4,086,709	2,130,628	1,956,081	52.1	47.9
1881-82..	4,309,387	2,258,013	2,051,374	52.4	47.6
1882-83..	4,723,198	2,356,560	2,366,638	49.9	50.1
1883-84..	5,455,609	2,853,235	2,602,374	52.3	47.7
1884-85..	5,711,165	2,903,764	2,807,401	50.8	49.2
1885-86..	5,474,941	3,027,192	2,447,749	55.3	44.7
1886-87..	6,174,871	3,142,423	3,032,448	50.9	49.1
1887-88..	5,695,178	2,959,040	2,736,138	52.0	48.0
1888-89..	5,851,304	2,778,384	3,072,920	47.5	52.5
1889-90..	6,780,714	2,772,896	4,007,818	40.9	59.1
1890-91..	7,307,562	3,213,168	4,094,394	44.0	56.0
1891-92..	7,485,517	3,619,348	3,866,169	48.3	51.7
1892-93..	7,203,405	3,410,608	3,792,797	47.3	52.7
1893-94..	8,265,445	3,955,415	4,310,030	47.9	52.1
1894-95..	9,238,258	3,932,950	5,305,308	42.6	57.4
1895-96..	7,903,168	3,146,614	4,756,554	39.8	60.2
1896-97..	8,644,472	3,182,880	5,461,592	36.8	63.2
1897-98..	8,579,275	3,207,965	5,371,310	37.4	62.6
1898-99..	8,883,029	3,354,891	5,528,138	37.8	62.2
1899-1900	9,587,321	3,423,049	6,164,272	35.7	64.3
1900-1901	10,772,532	4,083,586	6,688,946	37.9	62.1
1901-2...	12,204,178	4,569,537	7,634,641	37.4	62.6
1902-3...	10,980,859	4,641,787	6,339,072	42.3	57.7
1903-4...	11,573,715	4,753,511	6,820,204	41.1	58.9
1904-5...	10,698,952	5,185,530	5,513,422	48.5	51.5
1905-6...	15,625,111	7,541,661	8,083,450	48.2	51.8
1906-7...	16,224,402	8,223,326	8,001,076	50.7	49.3
1907-8...	15,553,082	7,744,218	7,808,864	49.8	50.2
1908-9...	16,313,857	8,554,637	7,759,220	52.4	47.6
1909-10..	16,711,014	9,333,007	7,378,007	55.8	44.2
1910-11..	19,044,256	9,456,668	9,587,588	49.6	50.4
1911-12..	17,665,304	9,962,951	7,702,353	56.4	43.6

TABLE XIII.—*Per capita consumption of sugar in various countries.*

[From Willett & Gray's Weekly Statistical Sugar Trade Journal, January 5, 1911, there credited to Otto Licht's Monthly Report, dated Magdeburg, December 9, 1910.]

Country.	Population.	Consumption per head.
		Pounds.
Germany	64,724,000	43.45
Austria-Hungary	51,018,000	25.14
France	39,450,000	37.80
Russia	128,171,000	22.82
Belgium	7,386,000	32.36
Holland	5,826,000	43.53
Sweden	5,476,000	53.90
Norway	2,350,000	41.78
Denmark	2,726,000	77.75
Italy	34,270,000	9.33
Spain	19,750,000	14.20
Roumania	6,800,000	9.50
Finland	2,969,000	32.45
Bulgaria	4,253,000	7.05
Greece	2,636,000	7.52
Servia	2,821,000	7.58
Turkey in Asia	24,050,000	12.89
Portugal and Madeira	5,760,000	14.12
Switzerland	3,559,000	64.10
England	45,472,000	86.30
Total Europe	459,527,000	32.60
United States (Willett & Gray, 1910)	91,972,266	81.60

TABLE XIV.—*Beet-sugar factories of the United States and Canada.*

Name of company or factory.	Location of factory (Pls. I and II, in pocket).	Built in—	Daily slicing capacity.
ARIZONA.			
			Tons.
The Southwestern Sugar & Land Co., main office, Phoenix.	Glendale	1904	800
CALIFORNIA.			
Alameda Sugar Co., main office, Hansford Building, San Francisco.	Alvarado	1879	800
Los Alamitos Sugar Co	Los Alamitos	1896-97	700
Spreckles Sugar Co., main office, 60 California Street, San Francisco.	Spreckles	1897-1899	3,000
Union Sugar Co., main office, Hansford Building, San Francisco.	Betteravia	1899	1,000
American Beet Sugar Co., main office, 32 Nassau Street, New York. Pacific coast office, 16 California Street, San Francisco.	Chino	1891	900
	Oxnard	1898	2,000
Sacramento Valley Sugar Co	Hamilton City	1905	700

TABLE XIV.—*Beet-sugar factories of the United States and Canada*—Continued.

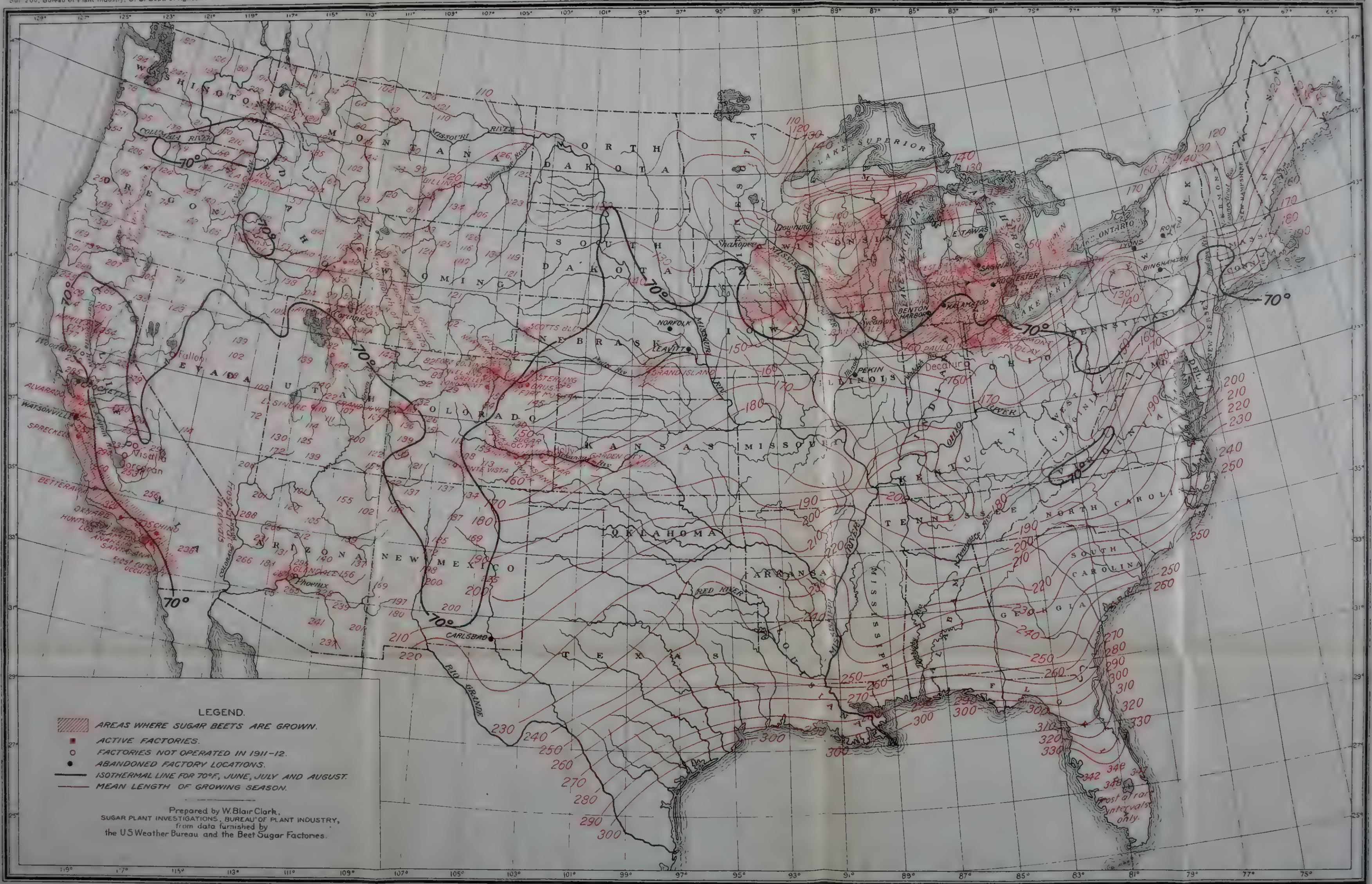
Name of company or factory.	Location of factory (Pls. I and II, in pocket).	Built in—	Daily slicing capacity.
CALIFORNIA—continued.			*Tons.*
Southern California Sugar Co.	Santa Ana	1908	600
Anaheim Sugar Co.	Anaheim	1910–11	600
Holly Sugar Co., main office, Boston Building, Denver, Colo.	Huntington Beach	1910–11	750
Total (10 factories)			11,950
COLORADO.			
American Beet Sugar Co., western office, 1530 Sixteenth Street, Denver.	Rocky Ford	1900	1,000
	Lamar	1905	400
	Las Animas	1907	700
Holly Sugar Co., main office, Boston Building, Denver.	Holly	1905	600
	Swink	1906	1,200
National Sugar Manufacturing Co.	Sugar City	1900	500
The Great Western Sugar Co., general offices, Sugar Building, Denver:			
Eaton factory	Eaton	1900–1902	600
Greeley factory	Greeley	1901–2	600
Loveland factory	Loveland	1901	1,200
Windsor factory	New Windsor	1903	600
Longmont factory	Longmont	1903	1,200
Fort Collins factory	Fort Collins	1903–4	1,200
Sterling factory	Sterling	1905	600
Brush factory	Brush	1906	600
Fort Morgan factory	Fort Morgan	1906	600
Western Sugar & Land Co.	Grand Junction	1899	600
San Luis Valley Beet Sugar Co.	Monte Vista	1910–11	600
Total (17 factories)			12,700
IDAHO.			
Utah-Idaho Sugar Co., main office, Salt Lake City, Utah.	Idaho Falls	1903	1,200
	Sugar	1904	1,200
	Blackfoot	1904	600
	Nampa	1906	750
Total (4 factories)			3,750
ILLINOIS.			
Charles Pope, 332 South Michigan Avenue, Chicago	Riverdale	1905	350
INDIANA.			
Holland-St. Louis Sugar Co.	Decatur	1911–12	1,000
IOWA.			
Iowa Sugar Co.	Waverly	1907	500
KANSAS.			
United States Sugar & Land Co.	Garden City	1906	900
MICHIGAN.			
Michigan Sugar Co., general offices, Saginaw:			
Bay City plant	Bay City	1899	600
Caro plant	Caro	1899	1,200
Alma plant	Alma	1899	750
Carrollton plant	Carrollton	1902	800
Sebewaing plant	Sebewaing	1902	600
Croswell plant	Croswell	1902	600
West Bay City Sugar Co.	Bay City, Station A	1899	600
Holland-St. Louis Sugar Co., main office, Holland	Holland	1899	350
	St. Louis	1903	600
Owosso Sugar Co., main office, Bay City:			
Owosso plant	Owosso	1903	1,200
Lansing plant	Lansing	1901	600
German-American Sugar Co.	Bay City, Station A	1901	650
Mount Clemens Sugar Co.	Mount Clemens	1902	600
Menominee River Sugar Co.	Menominee	1903	1,200
Holland-St. Louis Sugar Co.	St. Louis	1903	600
Continental Sugar Co., main office, 528 Garfield Building, Cleveland, Ohio: Blissfield works	Blissfield	1905	700
West Michigan Sugar Co.	Charlevoix	1902	600
Western Sugar Refining Co.	Marine City	1900	350
Total (17 factories)			12,000

TABLE XIV.—*Beet-sugar factories of the United States and Canada*—Continued.

Name of company or factory.	Location of factory (Pls. I and II, in pocket).	Built in—	Daily slicing capacity.
MINNESOTA.			*Tons.*
Minnesota Sugar Co	Chaska	1906	600
MONTANA.			
The Great Western Sugar Co., main office, Sugar Building, Denver, Colo.	Billings	1906	1,200
NEBRASKA.			
American Beet Sugar Co., western office, 1530 Sixteenth Street, Denver, Colo.	Grand Island	1890	350
The Great Western Sugar Co., main office, Sugar Building, Denver, Colo.	Scottsbluff	1900	1,200
Total (2 factories)			1,550
NEVADA.			
Nevada Sugar Co	Fallon	1910–11	500
OHIO.			
Continental Sugar Co., main office, 528 Garfield Building, Cleveland:			
Fremont works	Fremont	1900	500
Findlay works	Findlay	1911	600
German American Sugar Co	Paulding	1910	700
Total (3 factories)			1,800
OREGON.			
Amalgamated Sugar Co., main office, Ogden, Utah	La Grande	1898	400
UTAH.			
Amalgamated Sugar Co., main office, Ogden:			
Logan works	Logan	1901	600
Ogden works	Ogden	1898	400
Lewiston works	Lewiston	1905	600
Utah-Idaho Sugar Co., main office, Salt Lake City	Lehi	1891	1,200
Cutting station	Springville	1891	
Do	Spanish Fork	1891	
Do	Provo	1891	
Utah-Idaho Sugar Co	Garland	1903	1,200
	Elsinore	1910–11	500
Total (5 factories)			4,500
WISCONSIN.			
Wisconsin Sugar Co., main office, Milwaukee	Menomonee Falls	1901	500
Chippewa Sugar Co., main office, Milwaukee	Chippewa Falls	1904	600
Rock County Sugar Co	Janesville	1904	600
United States Sugar Co	Madison	1906	600
Total (4 factories)			2,300
CANADA.			
Dominion Sugar Co. (Ltd.), main office, Wallaceburg, Ontario:			
Wallaceburg plant	Wallaceburg, Ontario	1901–2	850
Berlin plant	Berlin, Ontario	1901–2	600
Knight Sugar Co	Raymond, Alberta	1904	400
Total (3 factories)			1,850
NOT IN OPERATION.			
Pacific Sugar Corporation, main office, Corcoran, Cal	Visalia, Cal	1905–6	400
	Corcoran, Cal	1907–8	600
Washington State Sugar Co., main office, Spokane, Wash.	Waverly, Wash	1899	500

Bul. 260, Bureau of Plant Industry, U. S. Dept. of Agriculture.

PLATE II


LEGEND.
▨ AREAS WHERE SUGAR BEETS ARE GROWN.
■ ACTIVE FACTORIES.
○ FACTORIES NOT OPERATED IN 1911-12.
● ABANDONED FACTORY LOCATIONS.
ISOTHERMAL LINE FOR 70°F, JUNE, JULY AND AUGUST.
MEAN LENGTH OF GROWING SEASON.
WASHINGTON
OREGON
IDAHO
MONTANA
WYOMING
NEVADA
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
PENNSYLVANIA
NEW YORK
NEW JERSEY
DEL.
MD.
CONN.
MASS.
VERMONT
NEW HAMPSHIRE
MAINE
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
COLUMBIA RIVER
MISSOURI RIVER
MISSISSIPPI RIVER
RED RIVER
RIO GRANDE
OHIO RIVER
70°
Frost at rare intervals only.
Frost at rare intervals only.
CARLSBAD
NORFOLK
LEAVITT
GRAND ISLAND
STERLING
FORT MORGAN
GARDEN CITY
MONTE VISTA
PEKIN
Decatur
BENTON HARBOR
KALAMAZOO
ROCHESTER
SAGINAW
E.TAWAS
LYONS
ROME
BINGHAMTON
Shakopee
Downing
Phoenix
GLENDALE
Fallon
Visalia
Corcoran
WATSONVILLE
ALVARADO
SPRECKELS
BETTERAVIA
OXNARD
HUNTINGTON BEACH
LOS ALAMITOS
ANAHEIM
SANTA ANA
CHINO
CROCKETT
Woodland
HAMILTON CITY
BILLINGS
LOVELAND
GREELEY
LONGMONT
BRUSH
SUGAR CITY
SCOTTS BLUFF
LEHI
GARLAND
PAULDING
FINDLAY

Prepared by W. Blair Clark,
SUGAR PLANT INVESTIGATIONS, BUREAU OF PLANT INDUSTRY,
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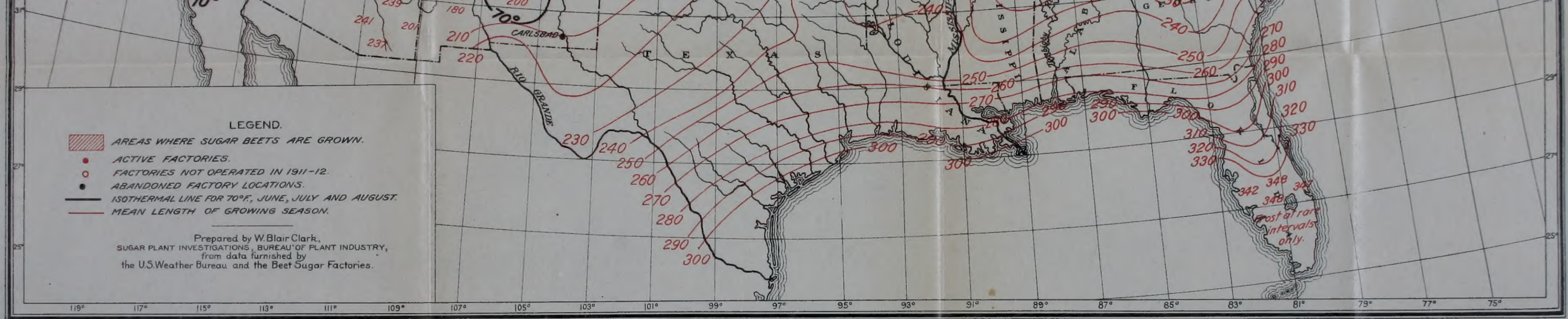

LEGEND.
AREAS WHERE SUGAR BEETS ARE GROWN.
ACTIVE FACTORIES.
FACTORIES NOT OPERATED IN 1911-12.
ABANDONED FACTORY LOCATIONS.
ISOTHERMAL LINE FOR 70°F, JUNE, JULY AND AUGUST.
MEAN LENGTH OF GROWING SEASON.
TEXAS
CARLSBAD
RIO GRANDE
70°
Frost at rare intervals only.
119° 117° 115° 113° 111° 109° 107° 105° 103° 101° 99° 97° 95° 93° 91° 89° 87° 85° 83° 81° 79° 77° 75°
210 220 230 240 250 260 270 280 290 300 310 320 330 342 348

Prepared by W. Blair Clark,
SUGAR PLANT INVESTIGATIONS, BUREAU OF PLANT INDUSTRY,
from data furnished by
the U.S. Weather Bureau and the Beet Sugar Factories.

FROST DATA FOR THE SUGAR BEET SECTIONS.

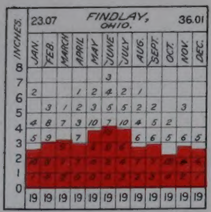
		N.W. OHIO		SOUTHERN MICHIGAN				N. ILL.	SOUTH'N WISCONSIN			N. WIS.		N. MICH.		MINN.	IA.	NEB.
		FINDLAY	WAUSEON	ADRIAN	ALLEGAN	LANSING	ALMA	SYCAMORE	WAUKESHA	MADISON	LANCASTER	DOWNING	SHAWANO	MENOMINEE	CHARLEVOIX	SHAKOPEE	WAVERLY	GRAND ISLAND
YEARS OF RECORD.		19	42	10	18	14	11	19	18	18	18	9	11	11	10	14	16	16
SPRING FROSTS AFTER	APRIL 30	13	36	10	17	11	11	14	15	8	10	9	9	11	10	10	10	8
	MAY 10	5	23	4	12	4	7	6	8	2	4	9	8	4	8	8	3	4
	MAY 20	2	10	1	7	1	1	2	7	0	2	6	6	2	1	6	1	1
FALL FROSTS BEFORE	SEPT. 20	1	9	1	2	0	2	4	0	0	3	6	3	1	0	4	1	3
	OCT. 5	10	28	4	11	3	6	9	7	4	11	9	8	8	1	11	6	6
	OCT. 20	14	38	8	17	11	10	16	14	13	15		11	11	7	14	14	13
DAYS IN GROWING SEASON LESS THAN	110		1	0	1	0	0	0	0		0	3	0	0	0	1	0	0
	130	0	14	3	6	1	4	3	2	0	3	8	6	3	1	4	1	1
	150	6	28	3	10	2	9	7	7	1	7	9	9	9	5	12	5	4
	170	14	38	8	17	12	11	16	11	8	14		11	11	10	14	12	11
		SOUTHERN LAKE SECTION										NORTHERN LAKE SECTION					CENTRAL PLAINS	

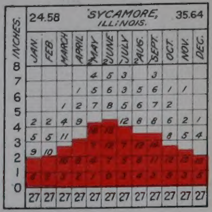
		MONT.	NEB.	N. E. COLORADO			S.W. KANS.	S.E. COLORADO				W. COLO.	UTAH		IDAHO		ORE.	NEV.
		BILLINGS	GERING & SCOTTSBLUFF	FORT MORGAN	GREELEY	FORT COLLINS	GARDEN CITY	HOLLY	LAMAR	LAS ANIMAS	ROCKY FORD	GRAND JUNCTION	FILLMORE	CORINNE	IDAHO FALLS	BOISE	LA GRANDE	FALLON
YEARS OF RECORD.		12	16	13	17	20	17	11	17	19	20	20	19	15	7	13	16	7
SPRING FROSTS AFTER	APRIL 30	12	16	12	12	16	6	5	6	12	13	3	17	13	7	4	16	7
	MAY 10	6	11	7	5	9	4	3	0	6	5	2	16	10	5	2	13	7
	MAY 20	3	3	6	1	4	2	1		1	1	0	8	3	4	1	9	5
FALL FROSTS BEFORE	SEPT. 20	8	4	4	4	9	2	2	2	3	3	1	8	3	6	0	11	2
	OCT. 5	12	13	11	12	16	4	4	6	8	9	3	16	9	7	2	14	4
	OCT. 20	14	15	15	15	19	13	11	15	18	19	11	19	14		6	16	6
DAYS IN GROWING SEASON LESS THAN	110	2	2	2	0	1			0	0			5	2	4		6	0
	130	7	7	3	3	10	0	0	1	2	0	0	12	2	5	0	12	4
	150	10	15	8	12	14	5	3	2	8	9	2	17	10	7	1	15	5
	170	12	15	12	15	19	11	10	12	15	16	5	18	13		4	16	7
		YELLOWSTONE VALLEY	PLATTE VALLEY				ARKANSAS VALLEY					GRAND VALLEY	SALT LAKE BASIN		SNAKE VALLEY			

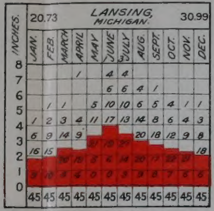
		CALIFORNIA								ARIZONA
		CHICO	WOODLAND	LIVERMORE	KING CITY	SANTA MARIA	LOS ANGELES	ANAHEIM	CHINO	PHOENIX
YEARS OF RECORD.		15	15	15	15	15	15	13	15	16
SPRING FROSTS AFTER	JAN. 31	12	10	9	5	7	0	3	7	13
	·FEB. 28	11	4	6	3	4		2	2	4
	MAR. 31	4	1	2	2	1		1	0	0
FALL FROSTS BEFORE	NOV. 20	5	2	3	3	3			0	3
	DEC. 10	8	10	5	6	7	0	0	4	9
	JAN. 1	11	15	10	6	11	1	2	6	16
DAYS IN GROWING SEASON LESS THAN	250	6	1	3	3	3		1	0	2
	275	10	4	6	3	5		1	1	3
	300	10	7	7	4	5		2	4	9
	325	10	11	9	5	8	0	2	6	13

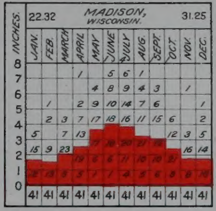
MAP OF THE UNITED STATES, SHOWING AREAS WHERE SUGAR BEETS ARE GROWN, SUGAR-FACTORY LOCATIONS, FROST DATA, AND LENGTH OF THE GROWING SEASON.

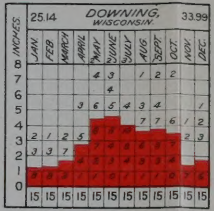
Gov. Doc. U.S. Plant Industry, Bureau of
U.S. " Bulletin.
P.

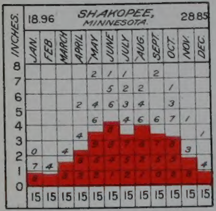


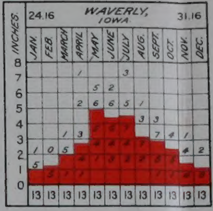


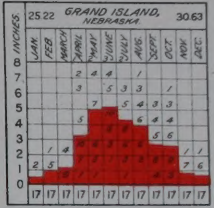


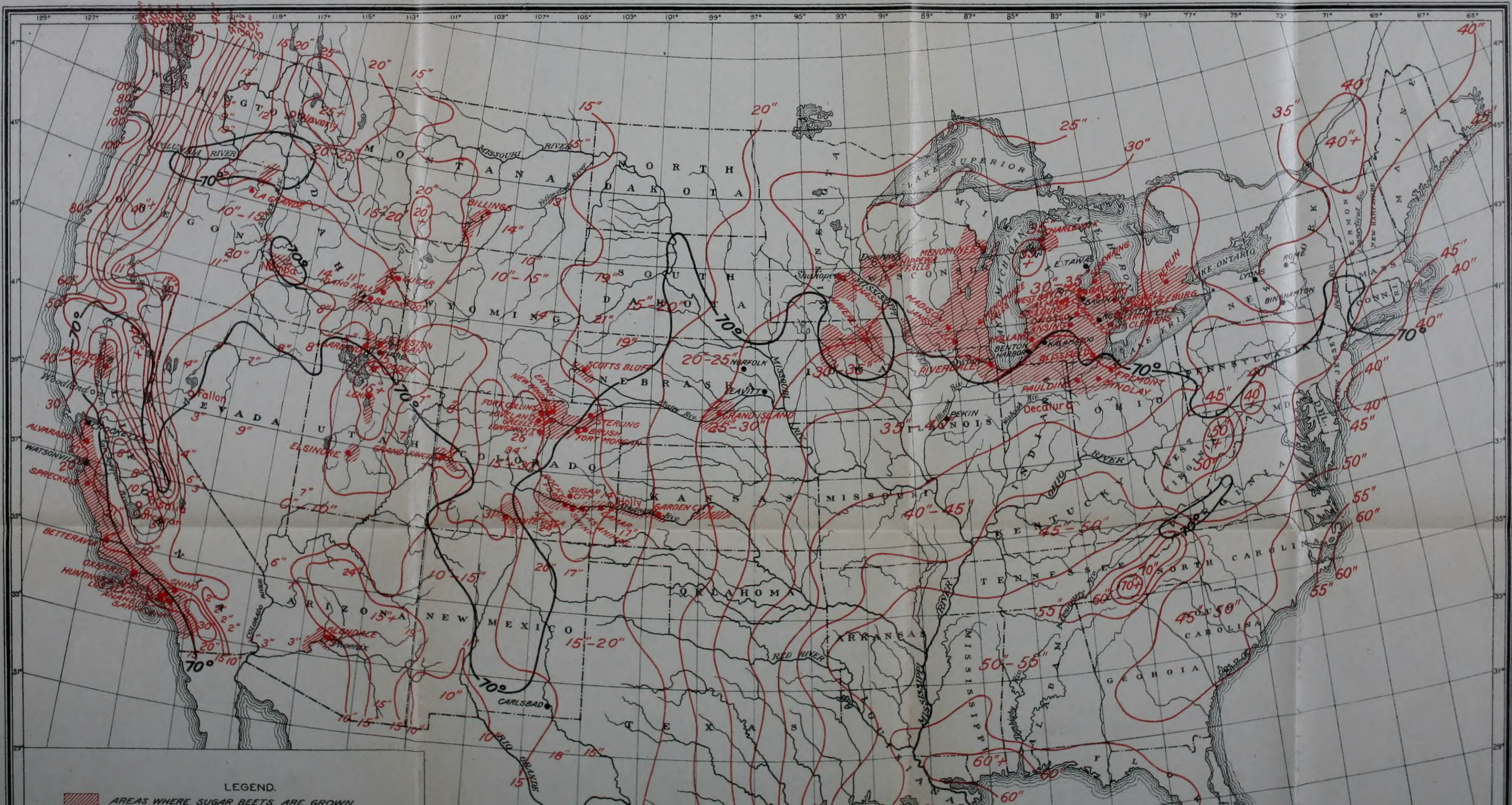


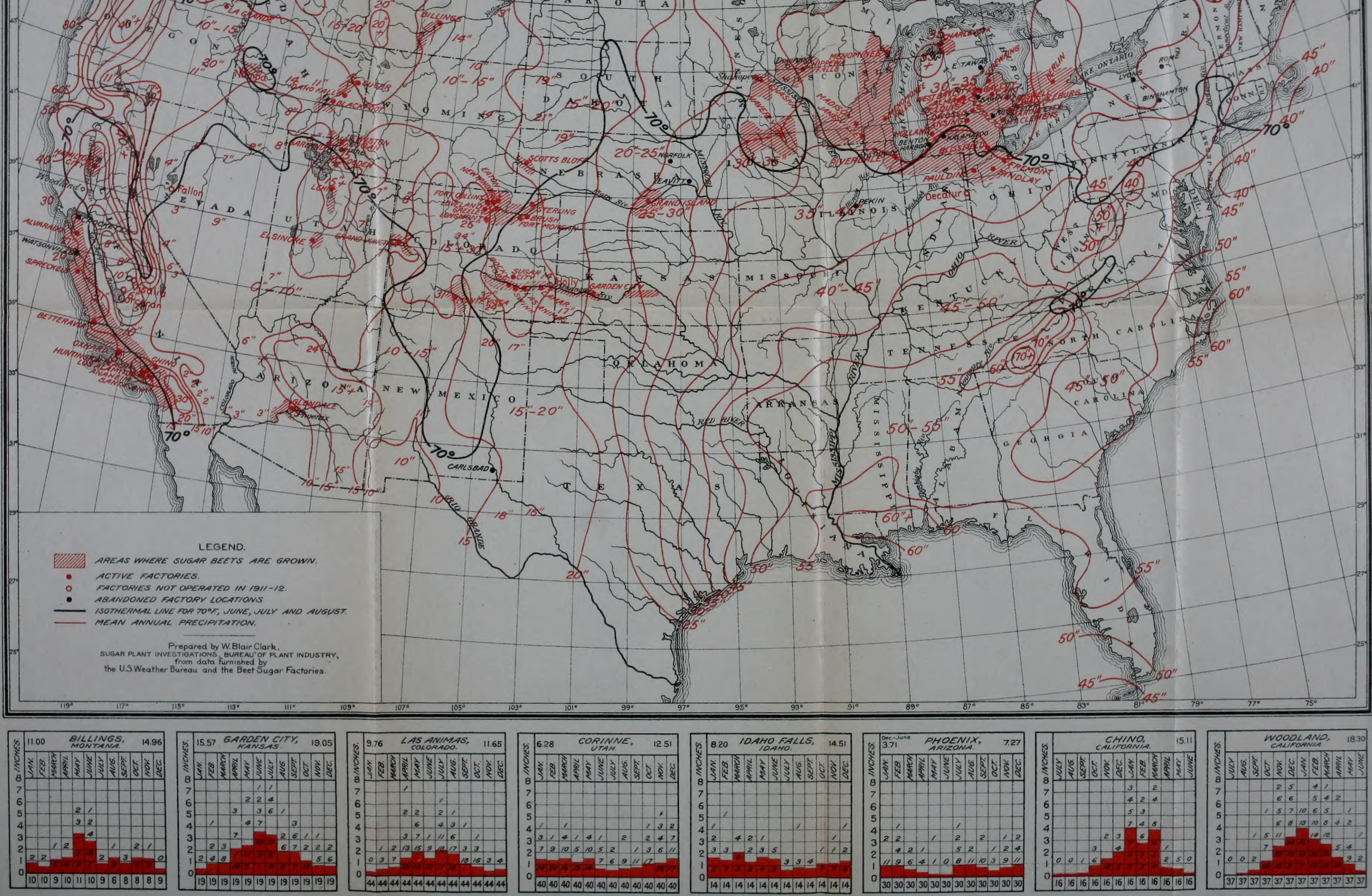









LEGEND.
▨ AREAS WHERE SUGAR BEETS ARE GROWN.
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
WYOMING
NEBRASKA
COLORADO
KANSAS
OKLAHOMA
TEXAS
NEW MEXICO
ARIZONA
UTAH
NEVADA
IDAHO
OREGON
WASHINGTON
MINNESOTA
IOWA
MISSOURI
ARKANSAS
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
PENNSYLVANIA
NEW YORK
MAINE
VERMONT
NEW HAMPSHIRE
MASS.
CONN.
N. J.
DEL.
MD.
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
MISSOURI RIVER
RED RIVER
RIO GRANDE
OHIO RIVER
70°
BILLINGS
LA GRANDE
SUGAR
BLACKFOOT
IDAHO FALLS
NAMPA
LEHI
GARLAND
ELSINORE
GRAND JUNCTION
FORT COLLINS
LOVELAND
GREELEY
LONGMONT
EATON
STERLING
BRUSH
FORT MORGAN
SCOTTS BLUFF
GRAND ISLAND
NORFOLK
LEAVITT
SUGAR CITY
ROCKY FORD
HOLLY
GARDEN CITY
LAMAR
CARLSBAD
GLENDALE
PHOENIX
ALVARADO
WATSONVILLE
SPRECKELS
BETTERAVIA
OXNARD
HUNTINGTON BEACH
LOS ALAMITOS
ANAHEIM
SANTA ANA
CHINO
HAMILTON CITY
WOODLAND
FALLON
WAVERLY
SHAKOPEE
DOWNING
CHIPPEWA FALLS
MENOMINEE
MADISON
JANESVILLE
RIVERDALE
PEKIN
DECATUR
HOLLAND
BENTON HARBOR
KALAMAZOO
BLISSFIELD
FREMONT
FINDLAY
PAULDING
CHARLEVOIX
EAST TAWAS
SEBEWAING
BERLIN
LYONS
ROME
BINGHAMTON
10" 15" 20" 25" 30" 35" 40" 45" 50" 55" 60"


LEGEND.
▨ AREAS WHERE SUGAR BEETS ARE GROWN.
● ACTIVE FACTORIES.
○ FACTORIES NOT OPERATED IN 1911-12.
● ABANDONED FACTORY LOCATIONS.
ISOTHERMAL LINE FOR 70°F, JUNE, JULY AND AUGUST.
MEAN ANNUAL PRECIPITATION.
BILLINGS, MONTANA. 11.00 14.96
GARDEN CITY, KANSAS. 15.57 19.05
LAS ANIMAS, COLORADO. 9.76 11.65
CORINNE, UTAH. 6.28 12.51
IDAHO FALLS, IDAHO. 8.20 14.51
PHOENIX, ARIZONA. Dec-June 3.71 7.27
CHINO, CALIFORNIA. 15.11
WOODLAND, CALIFORNIA. 18.30
INCHES.

Prepared by W. Blair Clark,
SUGAR PLANT INVESTIGATIONS, BUREAU OF PLANT INDUSTRY,
from data furnished by
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ENGRAVED AND PRINTED BY THE U.S.GEOLOGICAL SURVEY

MAP OF THE UNITED STATES, SHOWING AREAS WHERE SUGAR BEETS ARE GROWN, SUGAR-FACTORY LOCATIONS, AND PRECIPITATION DATA.